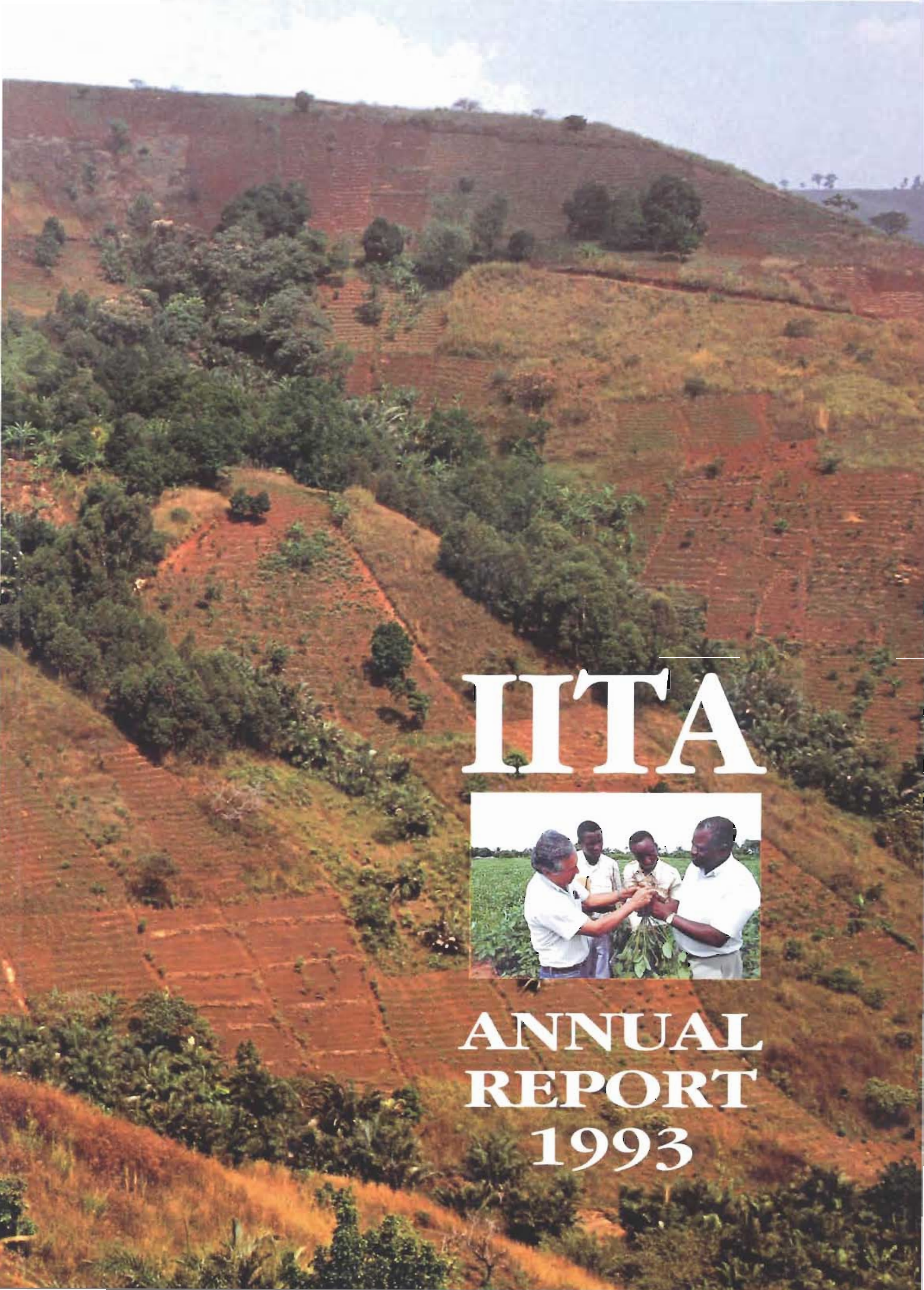


IITA

ANNUAL REPORT 1993

ABOUT IITA

IITA was founded in 1967 as an international agricultural research institute with a mandate for specific food crops, and with ecological and regional responsibilities to develop sustainable production systems in Africa. It became the first African link in the worldwide network of agricultural research centers known as the Consultative Group on International Agricultural Research (CGIAR), formed in 1971.

The Ford and Rockefeller foundations provided initial planning and financial support for IITA. The Nigerian government provided 1,000 hectares of land for a headquarters site and research farm at Ibadan, Nigeria. Funding for IITA comes from the cgiar and bilaterally from national and private donor agencies.

IITA is governed by an international board of trustees and is staffed by approximately 150 scientists and other professionals from about 40 countries and 1,400 support staff. Most of the staff are located at the Ibadan campus, while others are at stations and work sites in other parts of Nigeria and in the countries of Benin, Burkina Faso, Cameroon, Congo, Côte d'Ivoire, Ghana, Malawi, Mozambique, and Uganda.

IITA conducts research, training, and germplasm and information exchange activities in partnership with regional and national programs in many parts of sub-Saharan Africa. The research agenda addresses crop improvement, plant health, and resource and crop management within a farming systems framework. Research focuses on smallholder cropping systems in the humid and subhumid tropics of Africa and on the following major food crops: cassava, maize, plantain and banana, yam, cowpea, and soybean.

The goal of IITA's research and training mission is to improve the nutritional status and well-being of low-income people of the humid and subhumid tropics of sub-Saharan Africa.

Global links. Cosponsored by the World Bank, the Food and Agriculture Organization of the United Nations (FAO), and the United Nations Development Programme (UNDP), the CGIAR is an informal association of over 40 governments, international organizations, and private foundations. The CGIAR provides the main financial support for IITA and 17 other international centers around the world, whose collective goal is to improve the quantity and quality of food production in developing countries.


Lukas Brader

Director General's Report

The year 1993 brought exceptional challenges for IITA, calling for hard decisionmaking but bringing its rewards as well. We largely succeeded in maintaining the quality and intensity of our research efforts, despite funding cutbacks. We could accomplish that because of the commitment of our staff to our mission and the sustained encouragement of our partners in national programs.

Nevertheless, the funding shortfalls of 1993 jolted us at a critical time, the end of our first medium-term plan (1989–1993), which has been shaken by cuts in donor contributions for three of its five years. By its very nature, agricultural research needs long-term support to succeed, and collaborative relationships that are nurtured through confidence in the future. The spate of funding cuts has affected this research environment somewhat—but we have drawn on the good news of some of the year's results to sustain our essential optimism.

We are happy to report in these pages, here and in subsequent sections, our most important successes of 1993. For example, we released 14 disease-resistant plantain-banana hybrids in the public domain. The agricultural authorities in Ghana released 3 improved cassava varieties which we had developed together. Several long-term multilateral projects came to a successful conclusion. We undertook new responsibilities in linking our work in sustainable agriculture with "Agenda 21" of the Earth Summit in 1992. We worked out new perspectives in collaboration in Africa with sister institutes in the Consultative Group on International Agricultural Research (CGIAR). And with the election of one of our trustees, Dr Jacques Diouf of Senegal, as Director General of the United Nations Food and Agriculture Organization (FAO), we feel encouraged by the thought that our goals have been carried to the world's premier organization for agricultural development.

Core cuts

Donor cuts do take their physical and psychological toll of our activities, nonetheless. Our core budget for 1993 amounted to US$20.8 million, which was $2 million short of what the CGIAR's Technical Advisory Committee (TAC) had decided in principle was the amount we needed to achieve our medium-term plan objectives. For the previous year, 1992, we had received $21.3 million, which was short by $0.9 million of TAC's approved figure to meet that year's planned requirements.

The trend continues into 1994, when we launch a new 5-year plan but expect to face a gap of some $4 million between the TAC-approved planning figure and available funds.

From the first cuts to the core budget, in 1991, through 1993, we were able to sustain our research capacity by reducing administrative and operational spending. With the shortfall in the planned 1993 budget we must, for the first time, sacrifice part of our long-term capability to produce results. For the time being, we have reduced our primary scientific positions from the 59 planned for 1993 to only 49. At this time of writing, we feel renewed hope that future funding possibilities are promising, as the CGIAR takes constructive new steps and mounts a vigorous campaign among donors.

The research program will, during 1994, be reorganized into projects which will be funded according to their priority in an institutewide perspective. We will thus be able to respond to budgetary developments in a systematic way.

On the administrative side, we have contained expenditure over the years to an extraordinary extent. A high proportion of our costs is fixed, no matter the number of our staff; so costs per senior-scientist-year could be expected to increase as we reduce staff numbers. However, we have managed to ***reduce*** our real costs, taking inflation into account, during the 5-year plan period.

We also had to take measures that affect us personally—international staff are receiving no increment in salary for 1994, and some benefits have been reduced.

We are mindful that our sister institutes and other research organizations have experienced similar jolts. We are all regrouping under the forced austerity, while striving to retain program balance. In addition, IITA has its "township" to support, the community living facilities within our headquarters research station, while maintaining constructive activities with many sub-Saharan national programs.


Equi Nwulu

New hybrid to fight a black plague

West and East

In continuing to take our research and training activities to the agroecological zones where our collaborators will use the results, we reached two milestones during 1993. We signed agreements with the governments of Côte d'Ivoire (in March) and Uganda (in June) which will strengthen our partnership with the research systems in those countries.

The initiative in the moist savanna zone at Ferkessedougou, Côte d'Ivoire (which is described on page 41) will provide a focal point for maize improvement work in the moist savanna zone of West Africa.

In Uganda, IITA has built a regional research center for collaborative research on cassava, banana, and plantain with 15 East and Southern African countries. The new center is based at Uganda's long-established research station at Namulonge, near Kampala.

New releases

From the results of our research in hybrid plantains with resistance to black sigatoka, a fungal disease which is the main constraint in plantain production worldwide, we registered 14 improved genotypes in the public domain for unrestricted use. (See story on page 23.) In another development, 7 years of trials have demonstrated that sustainable crop and resource management practices can enable perennial production of plantain.

In Ghana, the government released 3 improved cassava varieties during October 1993 with local names. We had helped develop them over a 5-year program of trials in 8 locations in the major Ghanaian agroecological zones.

Commercial companies made seed of several IITA grain varieties available during 1993: in Nigeria (maize, soybean, and cowpea) and Mozambique (maize and cowpea).

In biotechnology, during the year we established a monoclonal antibody production lab at IITA, in collaboration with Agriculture Canada. We made new collaborative arrangements with the John Innes Institute in the UK, for 6 biotechnology projects in banana, cowpea, and yam improvement.

We perceive that modern biotechnological research is approaching the stage of public impact in African countries, so governments must prepare themselves to deal with issues of safety and acceptability of the results. The Nigerian government requested us to begin working with them, in 1993, to help develop biosafety guidelines for biotechnology in agriculture.

An era ends

Large-scale projects in several countries ended during 1993 after completion of a variety of tasks. Long-term, in some cases multicountry, projects were part of an approach to investment in agricultural research during the 1970s and 1980s, when the overriding concern was to strengthen national research infrastructure and equip scientists with new crop technologies for adaptation to local conditions.

Mayo Bolarin

Allies against downy mildew in Nigeria

The Semi-Arid Food Grains Research and Development (SAFGRAD) project closed in December after 17 years during which IITA gave substantial technical support in maize and cowpea improvement, in the Sahelian region. We will continue to work with the 8 countries that are carrying their collaboration forward in a new network for maize research: the West and Central Africa Maize Network (WECAMAN).

Scientific manpower development and maize research have shown extraordinary impact in Cameroon as a result of our collaboration with National Cereals Research and Extension (NCRE), a long-term bilateral aid project which has been scheduled to end in 1994.

The East and Southern Africa Root Crops Research Network (ESARRN) ended in September after 7 years of support to root crops research among 11 East and Southern African countries. Its work has devolved to two new subregional networks, the East Africa Root and Tubers Research Network (EARRNET) and Southern Africa Root Crops Reseach Network (SARRNET), to which IITA will continue to give technical support. Both commenced operations in October: EARRNET among 5 East African countries, from its new base at Uganda's Namulonge research station; and SARRNET among 10 Southern African countries from Lilongwe, Malawi.

Also in Southern Africa, IITA concluded 3 years of cowpea breeding and production improvement, as well as strengthening of research capability, in Mozambique with the Cowpea Research Project of the Southern African Development Community (SADC). The Mozambique branch of World Vision, an international nongovernmental organization (NGO), plans to support adaptive research and multiplication of selected cowpea varieties.

New partners and partnerships

In other respects we have been setting the stage for future work with NGOs to flourish.

Mayo Bolarin

We organized a meeting with NGOs that work in Africa, to begin building a partnership with them. (See story on page 42.) NGOs in several countries are growing into a strong source of support for agricultural development, in response to expressed needs from farmers and urban groups.

As concepts began to develop within the CGIAR, about how research should be organized in the world's developing regions on the basis of agroecological zones (the so-called "ecoregional" approach), IITA was designated the convening center for sister institutes working in the warm humid and subhumid tropics of Africa south of the Sahara—that is, West, Central, and East Africa and Southern Africa.

In tandem with these beginnings in operationalization of the ecoregional approach, IITA has been considering how best to respond to the environmental imperatives set out at the Earth Summit (the United Nations Conference on Environment and Development—UNCED), in its "Agenda 21". Our work in resource management in the humid forest zone (see "Research perspectives" and highlights on pages 10-11) relates strongly to those concerns. In addition, our Plant Health Management Division has been invited to take the lead in organizing an action plan for integrated pest management for the CGIAR that responds to the global priorities.

To encourage wide discussion of UNCED conclusions and how action could best evolve among Africa's community of research and development organizations, IITA invited Mostafa Tolba, the former executive director of the United Nations Environment Programme, to give the fourth in IITA's series of Distinguished African Scientist Lectures. In April, Dr Tolba spoke on "The Earth Summit and Africa's development".

We worked closely with the World Bank-sponsored Special Program for African Agricultural Research (SPAAR) during the year to develop a framework for action in the humid forest and moist savanna zones of West and Central Africa.

In 1993 we agreed with CIMMYT on regional responsibilities for research and training in maize varietal development and testing. IITA is responsible for maize improvement and crop management in West and Central Africa, while CIMMYT takes responsibility in East and Southern Africa. Plant health management is IITA's responsibility continentwide. Both centers encourage and will jointly coordinate exchanges in maize germplasm, information, and training.

As a result of the CG review of rice across the system, WARDA and IITA have agreed on common areas of research interest and collaboration: long-term storage of West African rice germplasm at IITA, integration of training programs, hosting of research activities according to location, and joint governance of specific research programs.

Growing confidence

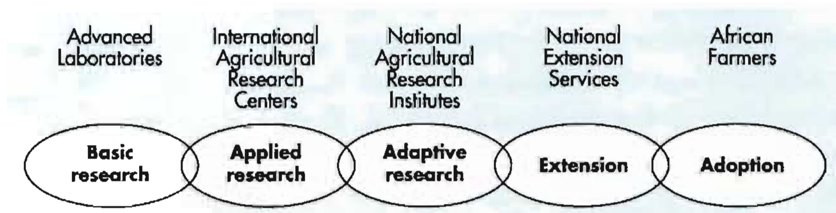
The environment in sub-Saharan Africa appears increasingly favorable for research initiatives.

National agricultural research institutions have developed their capabilities over the 25 years that IITA has been operating. They have been learning from each others' experience as well, through networking and exchanges with the international research centers. The international centers, on their part, have been refining their respective priorities and are improving mechanisms for inter-center collaboration in common areas of interest. In many countries, as a result of growing research capability and experience, a base of confidence has been building up which is essential to the success of scientific enterprise and which augurs well for the results of their ongoing work.

Development of scientific manpower and institutional facilities of national programs has triggered changes in IITA's relations with them. From the earlier, simpler conception of our mutual relationship as a process of "transfer of technology", we are moving at variable speeds—according to circumstances in each case—toward collaborative development of the research, from idea to process to adoption stages. We are working together to identify and then realize the opportunities for research to tackle a problem or make headway in improving on-farm food production.

In starting work in Africa as an international center, IITA sought to develop technologies for farmers which the national programs could test and adapt to conditions in their varied environments. IITA training programs emphasized crop production technologies and individual training. we saw ourselves at one link in a "chain" of research progress:

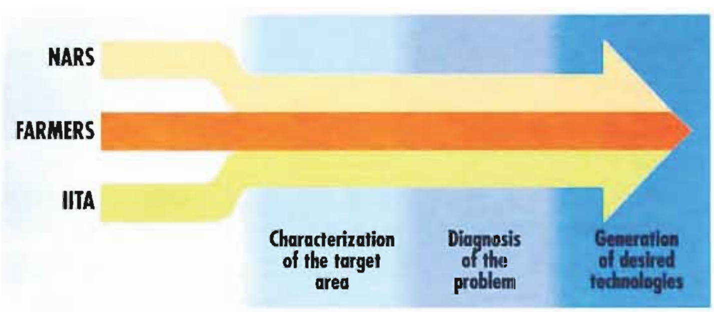
Chain of collaboration to produce improved agricultural technology for Africa



While national programs have grown stronger, IITA's understanding of the agricultural setting has deepened with experience in dealing with specific environmental and farmer requirements. Our own research and training role has changed along the way, so that we now work with the national programs in a conceptually different system which runs the gamut of the research-to-adoption process.

Moreover, for the results of this process to be truly effective and have the desired impact, the farmer must participate in the research with the national program and IITA. The farmer makes a vital contribution in identifying research needs and in determining the requirements of new technologies.

The new concept can be described more simply than its predecessor, although it is born of expanded awareness of the real complexity of agricultural development:



In this conceptualization of IITA's role and relation with national programs, the links of the earlier "chain" of research have merged into a continuum that proceeds from the onset of the research process to its resolution. Distinctions among basic, applied, and adaptive research, and extension and utilization phases, are no longer so clearcut as before.

At most steps along the way in the development of the research, all the concerned national as well as international collaborators may need to be involved because of the specificity of requirements for the desired technology. In this continuum, national and international researchers and farmers are partners in a joint venture, each contributing to the extent possible, depending on the mix of circumstantial factors. Ideally, collaboration achieves a collegial balance with effectively matched contributions at every stage.

Upstream/downstream on the continuum

In substantive terms, the nature of our joint research ventures can range from "upstream" to "downstream".

Upstream research involves generation of specialized information which countries require in development of a technology to alleviate a problem they have identified. One example is virus detection work with monoclonal antibodies, whereby virologists conduct diagnostic studies on crop viruses for control purposes and exchange information with IITA and interested countries. (See story on page 38.)

In another example, soil fertility decline and weed competition are problems common to most maize-producing countries, which have formed the Collaborative Group on Maize-Based Systems Research (COMBS) to address the basic issues and possible solutions together. (See story on page 19.)

Downstream research targets information on end-use requirements. Through on-farm trials, researchers and farmers deepen their mutual understanding of the factors which affect the on-farm use of technologies, including management practices and environmental and economic exigencies. Farmers' feedback helps scientists to improve design of new technologies and to deploy existing technologies in the field for optimal benefit. (See story on page 42.)

In summary, for effective research results, scientists from both national and international centers need to work together with farmers, along with others from NGOs, private companies, or other agencies with expertise and an interest in the outcome of improved farm productivity. Many aspects of the research process call for the unique qualities that each brings to the experience:

- sources of relevant information
- material resources to support the research
- experimental approaches with end-users/farmers
- different modes of interaction in accomplishment of the task
- different opportunities latent in each situation to be exploited—all require a collaborative relationship which succeeds in spotting and combining the right possibilities within the research setting.

Ecoregional approach

The evolution in collaborative relations corresponds with new developments in international research strategy: the "ecoregional" approach to the organization of research and training among all international centers.

IITA and sister institutes are reorganizing their activities with reference to the broadly defined agroecological conditions which govern agricultural production. National boundaries were, of course, not necessarily drawn to coincide with agroecological zones—our map on page 9 shows how the forest and savanna zones cut across many of the same countries, with the forest zone falling within 13 different countries and the savanna within 30 countries. To help focus technical inputs to research within the zones that fall within a country, IITA will, during 1994, formulate its plans and activities on an ecoregional basis.


An ecoregionol view in Ghana

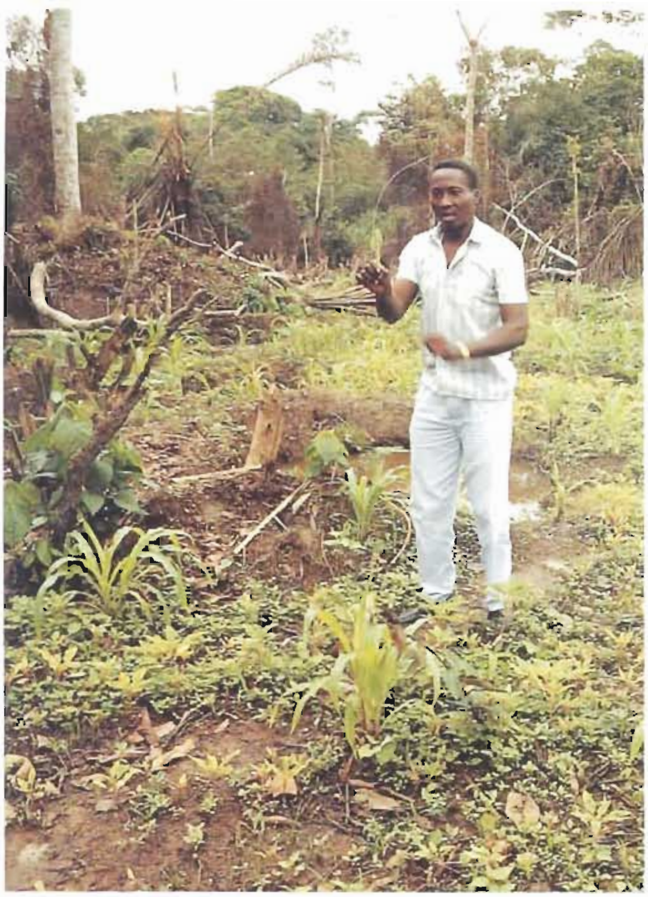
Scientifically, this approach makes good sense, because it refocuses everyone's attention on area-specific resource and crop management needs, which are the crux of agricultural production. Resource management must be location specific, in order that the resources be husbanded effectively for maximum benefit in production. Research can further determine the corresponding needs: improved crops, plant health management, and farmer practices that will respond optimally with the given resource base.

As an increasing proportion of IITA's research and training takes place in the agroecological target areas, and involves national researchers in the countries concerned, the activities become increasingly tailored to needs as they are perceived by national scientists. Whether collectively in regional groupings or within their own country, national scientists increasingly interpret the problems to be addressed and identify solutions to be sought, in collaboration with international centers that afford access to external resources. The collaborative relationship remains dedicated to the cause of improvement of farmers' productivity; however, the international centers increasingly seek to enable the national institutes to take the lead in setting and achieving research goals.

At IITA we see how the involvement of international centers in national agricultural research and training has renewed its purpose, its *raison d'être*.

with collaboration on an ecoregional basis. In the new model, our joint approach in the processes of characterization of the environmental setting, diagnosis of problems, identifying and developing of technologies to address the needs, adds impetus to the empowerment of the national programs, as well as promotes the chances for success in solving particular problems. That takes us as close as we can be, at present, to the ideal of self-reliance in agricultural development.

In this perspective, we commence a new plan period, 1994–1998, with the encouragement of our convictions and with hopes of replenished funding from donors who are also convinced about the importance of our work.



Egui Nwulu

Concern for protecting biodiversity in Cameroon

IITA and Agenda 21

At IITA, research has always sought wise ways and means to use resources for production, reap satisfying harvests, yet sustain the resource base through improved management for even better harvests in coming years.

Environment and sustainability have been at the center of its concerns since IITA opened in 1967, as agricultural problems in its mandate area have stemmed partly from adverse environmental changes. They are the concerns that the world community is promoting under the banner of the Earth Summit—the United Nations Conference on Environment and Development (UNCED)—of 1992 at Rio de Janeiro.

The Earth Summit produced an agenda for action, to address the challenges of the 21st century and beyond. "Agenda 21" sticks to principles—it describes current concepts of sustainable development and environmentally sound management of the earth's natural resource base, which should guide the development of conservation policies and activities.

RESEARCH PERSPECTIVES

Most environmental issues that affect agriculture relate to management of natural resources and conservation of genetic resources. Agenda 21 asks agricultural research systems to ensure that their work embodies the aims of resource management and conservation, so that production goals may be realized and the resource base maintained for future use.

During International Centers' Week at the end of 1993, the CGIAR agreed to focus its research on issues which address Agenda 21 priorities, where each center's own research domain relates to them. Generally for CG centers, the related concerns are:

- degraded lands and their marginalized populations
- genetic resources of crops, livestock, fish, and forests
- integrated pest management
- geographical information systems, with data on physical, biological, and social environments of the research domain.

IITA's research activities have focused on those concerns from the beginning of its first medium-term plan in 1989.

Soils Soil productivity is jeopardized under intensified use without restorative measures. Forests dwindle with overexploitation. Weeds gain ground and depress crop production; eventually they can cause farmers to abandon their land. Soil erosion can occur where sloping land is not protected.

To arrest the process before degradation becomes irreversible, IITA has pioneered research in conservative land clearing practices for tropical soils and in fallow management with leguminous species to restore soil nutrients.

Biodiversity IITA seeks to conserve genetic resources, mainly through preservation of crop genetic resources in long-term storage.

IITA collects germplasm of wild and cultivated species for use in development of high-yielding crop varieties that are adapted to specific environmental conditions. The aim is to stabilize farmers' production at increased levels that nonetheless are sustainable because of improved resource and crop management practices.

Ultimately, with stabilized production, farmers would not need to clear the remaining forest lands, as they now do. Through reduced forest destruction, improved land clearance and fallow management, and stabilized crop production, biodiversity would be protected in natural habitats.

Integrated pest management IITA's work toward integrated pest management in sub-Saharan Africa aims to sustain rather than destroy basic ecological relationships in the environment. Building on its success in biological control of the cassava mealybug in the 1980s, IITA is developing agroecologically sound strategies for habitat management against pest and disease attacks on crops. Appropriate combinations of biological control, pest-resistant crop genotypes, and cultural practices are employed to conserve the integrity of the food chain within the agroecosystem.

The guiding concept is manipulation of the environmental elements which cause the problem, rather than attempts at direct elimination which can fail because all the supporting factors in the problem cannot be controlled. Scientists in related disciplines help in designing the defence, which should combine several environmentally consonant methods in the expectation that they together can be more effective in the long run than any one applied alone.

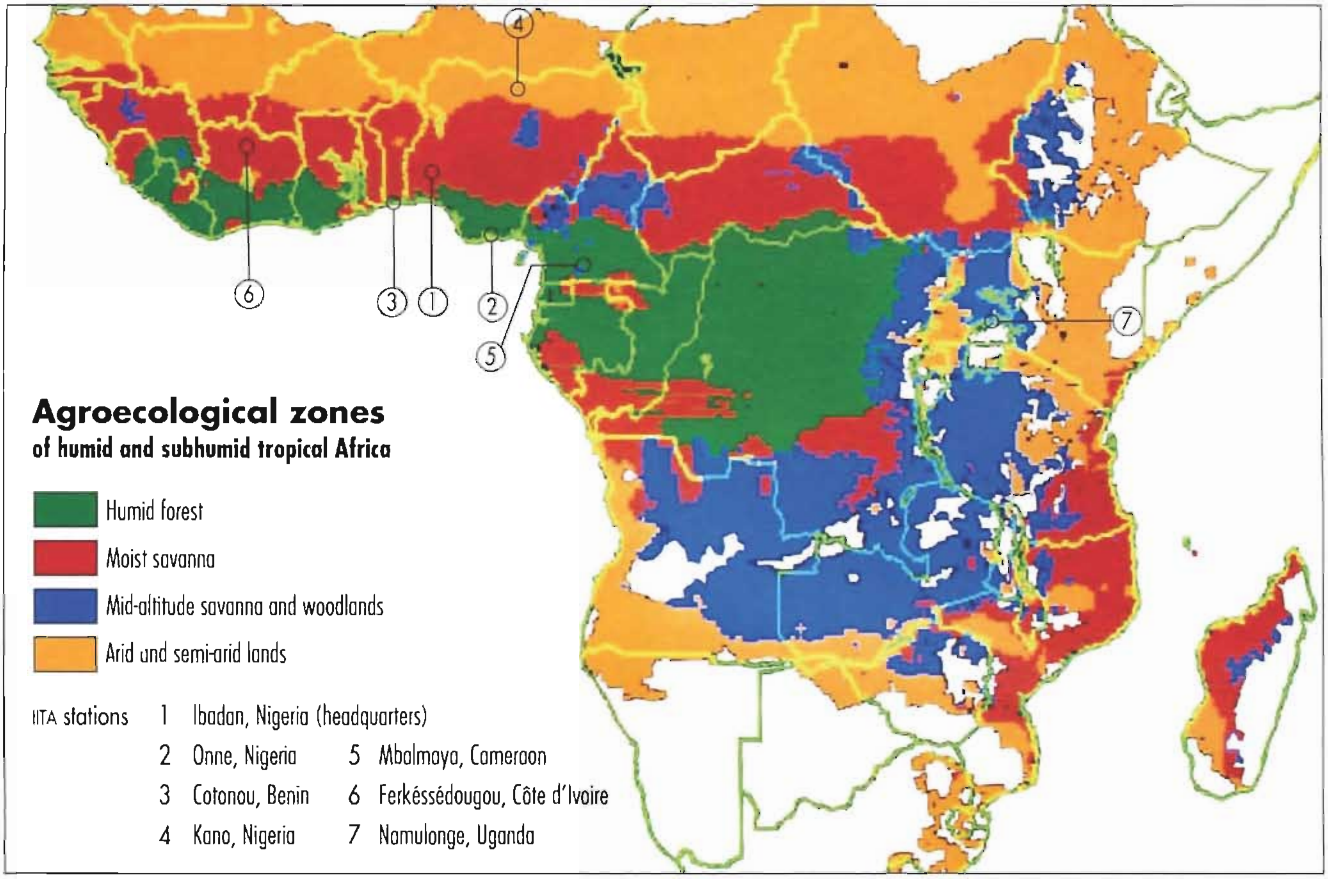
Resource information system In this vision of how to achieve agroecological sustainability, the key to effectiveness is the correct deployment of technologies that are designed to counter problems in their specific environmental settings. Both a full understanding of a problem and the design of a remedial technology require the right kinds of information on the characteristics of the situation and the needs to be met.

IITA is continuously renewing its resource information system, which contains the key agroecological characteristics of the African continent in areal units of 10 square miles (16 square kilometers). This system can generate maps such as the one on these pages that delineates the principal agroecological zones in IITA's mandate area. The system holds the database on which IITA research and technological development is founded.

Information technology is beginning to make sufficient quantities of data on environmental conditions available to researchers for analysis and use in solving such large-scale problems as soil

IITA and UNCED: Research on environmental issues

IITA Research Agenda	UNCED Program Area
Development of more productive and sustainable systems to replace slash-and-burn cultivation in the humid forest and moist savanna zones	Combating deforestation Sustainable agriculture and rural development Protecting the atmosphere
Collection and characterization of plant genetic resources (crops and multipurpose trees)	Conservation of biological diversity
Sustainability of different cropping systems in terms of nutrient cycling, soil structure, erosion control, reduced weed infestation and other indicators	Sustainable agriculture and rural development Managing fragile ecosystems
Development of pest and disease control measures' that avoid the use of chemicals	Sustainable agriculture and rural development



degradation. IITA is developing analytical approaches which exploit the volumes of data to characterize environmental conditions and the changes occurring through physical and socioeconomic causes. IITA has selected agroecologically representative "benchmark" sites where relevant observations will be recorded.

As knowledge about environmental characteristics and farmers' needs comes together with ideas for problem-solving technologies, IITA will be able to fit solutions to problems with improved efficacy.

During its second medium-term plan period, 1994-1998, IITA has expanded its commitment to research on environmental issues. IITA's research agenda directly relates to several major areas of concern outlined in Agenda 21, as listed in the accompanying panel.

Resource and Crop Management

Highlights 1993

The organization of the Division was streamlined to accord with the ecoregional framework adopted by the CGIAR. Inland valley research activities were incorporated into the humid forest and moist savanna programs, while the inland valley program was dissolved.

Moist Savanna Program

Resource management research and technology development included various legumes as components of sustainable cropping systems, as well as benefits to the soil from the biocycles of nitrogen-fixing legumes, soil organic matter, and soil bacteria. Legume-based, managed fallow systems have begun to show significant results in long-term, on-station research on sustainable cropping (see article on page 14).

Nutrient production capacity under a wide range of herbaceous and shrub legumes was studied together with their weed-suppressing and soil-improving abilities, for both the moist and derived savanna zones. Results showed *Mucuna pruriens* and *Centrosema pascuorum* to be best in biomass production and nodulation in soils of the moist savanna. Nodulation among herbaceous legumes varied widely in the moist savanna, and varied also with time after planting and soil type.

Studies of quantity and quality of soil organic matter focused on its source and associated crop management practices. The soil organic fraction (litter fraction) larger than 0.25 millimeters was identified as the most dynamic organic matter pool.

Fertility-restoring technologies with improved varieties of cowpea and groundnut were tested on farms in Bauchi State, at "benchmark" sites which are representative of market access and land and labor availability in the zone and which hold both agropastoral and crop-based farming communities. Non-governmental agencies in the area were contacted with a view to future enlistment in promotion of the most promising technologies.

Legume-based technologies are being developed and applied with farmers' participation in Benin, Cameroon, and Ghana with technical support from the Collaborative Group on Maize-Based Systems Research (COMBS), composed of West and Central African institutes (see article on page 17).

Alley cropping studies in the derived savanna (forest-savanna transition zone) revealed high nitrogen levels in roots of *Leucaena* and *Gliricidia* species. Half the roots of *Leucaena* were found to have penetrated below 60 centimeters under the soil surface, the deepest extent of maize and cowpea roots in alley cropping trials. In long-term trials, *Leucaena* was the hedgerow species associated with the highest maize yields, followed by *Gliricidia*.

Characterization of agricultural production in the moist savanna, with a focus on socioeconomic and agroecological features, continued with identification of 180 distinct cropping systems in 14 West and Central African countries. In looking at the dynamics of those systems, 84% of the agricultural production in that region was found to be "population-driven", while "market-driven" production accounted for 16%. (Data collection was completed in 1993. See related article on characterization of West African systems, on page 12.)

Humid Forest Program

Biophysical characterization of the humid forest zone continued at the 1,000-hectare Mbalmayo farm site, with studies primarily on soil acidity, weed dynamics, soil nutrient and organic matter dynamics, soil faunal activity, and impact of burning of residual biomass after forest clearing, which is a common farming practice.

A multidisciplinary approach was used in the study of the impact of various levels of burning on the soil's chemical and physical properties; nutrient flux; weed seed survival, establishment and growth; and crop growth and yield. Burning can be an effective management tool for farmers if there is balance between its beneficial effects (vegetation control, nutrient supply, weed suppression) and disruptive consequences (nutrient loss, destruction of soil structure, loss of organic matter).

Weed and vegetation management studies started at the southern Cameroon benchmark site. They include physical control measures against *Chromolaena odorata*, perceived as the farmers' primary weed problem, and the competitive ability of various cassava clones against weeds.

Existing alley cropping experiments were utilized in assessing the effects of pruning quality and quantity and management practice on soil organic matter, nutrient cycling, soil fauna activity, and soil physical properties. The results indicate that a fallow of even one year can positively impact on soil biological and physico-chemical factors.

The third and final phase of the Collaborative Study of Cassava in Africa (COSCA) continued with analyses of cassava processing, marketing, and consumption. COSCA organized workshops in 10 of the cassava-producing study countries for preparation of reports on earlier work: phases I (physical and social environmental characterizations) and II (production issues). Other reports on varieties under cultivation, processing, distribution, production trends, commercialization, and adoption of improved varieties were completed.

Characterization of the farmers' resource base and management practices in the humid forest zone continued with analysis of a 20-village diagnostic survey. Data were analyzed on tree species, plant associations, planting schedules, and fallow periods. Data on traditional and modern economic activities were analyzed to determine profitability, return on labor, and use of labor and capital. Scientists at IITA's Humid Forest Station, Nkolbisson (Yaounde) held a workshop on methodology, databases, and findings of the survey for Cameroonian colleagues at the *Institut de recherche agronomique* (IRA).

Related studies on the uses and marketing of non-timber forest products began and, initially, found that the net profit margin for such forest products was higher than that for food crops in local markets. Groundnut showed the highest profit margin among food crops. The study confirms the strategic importance of such forest products in forest preservation research.

A 2-year agro-ethnographic study in 4 villages near Mbalmayo was completed. It identified and characterized, for purposes of technological design, farmers' main uses of their fields. The study also evaluated critical village-level factors which shape farmers' resource management strategies, focusing on the availability, use and control of land and labor, on investment decisions and on social organization.

Alley cropping trials in the humid forest zone continued to assess how feasible is continuous cropping with hedgerows of different tree species and with different tillage pratices. In the third year of cropping, crop productivity showed no advantage from hedgerow prunings. Weed pressure was, however, reduced by the presence of hedgerows and by tilling of the soil. In farmer-managed trials, results showed that alley cropping holds little attraction for farmers so long as they have fertile plots of secondary forest available to them to clear and cultivate.

Agroecological studies

Baseline data were collected and analyzed for screening of IITA's mandate crops, focusing on water requirements, growing habit, potential productivity, light use, and optimal plant geometry and crop mixture. The information is used in selecting technologies which will be most productive in a given target area. Simulation models employ much of the data in predictive exercises which obviate the need for extensive agronomic trials. For example, preliminary findings with cereal/legume interactions showed that intercropping of maize and soybean does not significantly affect maize yield but does show greater efficiency in nitrogen-use than with sole-cropping.

The Agroecological Studies Unit provided IITA programs with data and maps on production potentials and constraints, for use in selection of survey or research sites. The Unit continued collaboration with 14 West and Central African national programs in macrocharacterization of agricultural systems, for development of sustainable technologies, which involves the use of geographical and resource information systems. Culminating 2 years of preparatory work, the Unit conducted a workshop for national collaborators on the uses of resource information systems in support of agricultural research, especially in setting priorities and implementing plans efficiently.

In the characterization of West African inland valley areas, as part of an investigation of their productive potential, computer-based "maps" (spatial digital-data layers) were created with IITA's methodology for regional mapping, which uses high-resolution satellite data from Landsat TM and Spot HRV.

The two study areas for 1993 included Kaduna, Nigeria and Save, Benin. Each area covered a full Landsat frame, or about 3.12 million hectares (a little larger in area than Rwanda). Groundtruthing was conducted to verify satellite imagery in 5 study areas within 6 West African countries: 4 areas in the moist savanna and 1 in the humid forest zone. To date, results reveal that intensity of inland valley cultivation increases significantly with dryness in climate, density of population, density of road network, and intensity of adjacent upland cultivation.

All study findings will be shared among the 11 members of the consortium for inland valley research in West Africa. Established in June 1993 for coordination of methodologies and plans for inland valley research, the members comprise 2 CG centers (IITA, WARDA), CIRAD, the Winand Staring Centre in the Netherlands, and 7 African national programs: of Benin, Burkina Faso, Côte d'Ivoire, Ghana, Mali, Nigeria, and Sierra Leone.

Agroforestry development

Evaluation of multipurpose trees and shrubs continued, with ICRAF collaboration, at Ibadan, the High Rainfall Station at Onne, and the Humid Forest Station at Mbalmayo, for their potential role in agroforestry technologies. Project activities grew to include germplasm collection and research on propagation techniques.

Postharvest technology

Three simple gadgets were released for use in the moist and dry savanna zones: a multicrop thresher, a grain polisher, and a grinder. During trials the thresher and polisher reduced postproduction losses (from deteriorіation and insects) and labor requirements by nearly two-thirds, for cereal and legume crops (variously for each machine): maize, sorghum, cowpea, millet, rice, and soybean. The grinder can accommodate most types of food crops. The Postharvest Technology Unit also modified oilpalm and groundnut oil-processing packages for semimechanized operations.

To conserve crop yields and improve efficiency in processing, the Unit studied the physical and mechanical properties of high-yielding soybean varieties, as well as harvesting and handling practices. Yield-saving practices which emerged during the year were harvesting at the right time of day and threshing immediately after harvesting.

The Unit established a network of trained manufacturers in 1993. Training activities included a 2-week course on manufacturing of postharvest tools and equipment, as well as training of postharvest engineers in-country in Benin (1 engineer), Malawi (2), and Nigeria (1).

Characterization

Pointing the way to optimal use of crop and land resources

Given that natural resources are finite and the human population is growing, better means need to be relentlessly pursued for using these resources to their optimal potential. That pursuit is a complex endeavor, which takes on an added urgency in sub-Saharan Africa, where food production per head has been declining in recent decades; in addition, the vastness of the area presents problems of heterogeneity, which often defy simple, homogeneous solutions.

A first step in characterizing how land is—and can be—used, for example, is describing the prevailing cropping systems and practices, as well as improved technologies, in terms of social and economic forces. IITA scientists have, over recent years, completed such a process of macrocharacterization for the humid and subhumid tropics in West and Central Africa.

Following recognized methods in economic analysis, a second step consists of understanding existing farming practices and agricultural systems in terms of such a characterization, so that improved technologies can be developed, tested, and/or adapted to suit varying demands and requirements.

A third step would be to attempt a matching of environmental requirements and improved technologies, so that "high potential" technologies can be matched with areas that provide them a high probability for successful adoption, without causing damage to the environment.

Land-use systems

Based on the work carried out so far, in active collaboration with colleagues in African national programs, IITA scientists have been able to describe land-use systems in terms of four broad socioeconomic scenarios, driven by either increased population density or market forces. These scenarios are (1) population-driven expansion; (2) population-driven intensification; (3) market-driven expansion; and (4) market-driven intensification. Because expansion is often not possible, especially in areas where problems of food crop production are most acute, IITA scientists have tended to analyze intensification more closely.

That choice is also supported by the fact that population-driven (54%) and market-driven (31%) intensification dominates the area, with population-driven land expansion covering only 12% and market-driven expansion a mere 3% of the land area studied in all of West Africa (see figure, opposite).

Population-driven intensification is characterized by subsistence production of food crops, with little or no purchased inputs. In areas where such intensification occurs, the resource base tends to be seriously degraded, because (1) fertilizer use is low (so the soil nutrients cannot be replenished), and (2) continuous cropping, with short or no fallow periods, leads to pest buildup, especially of weeds. Low levels of cash availability in these areas further constrain the capacity to absorb new technolgy or to use purchased inputs for maintaining the resource base.

Market-driven intensification, in contrast, is characterized by production of a profitable cash crop *, using purchased inputs. It also depends upon good transport systems, favorable government policies (to provide an enabling context), and most importantly, technologies that ensure sustained production of cash crops at relatively high levels of profit.

Before such a classification of scenarios can be applied effectively in agricultural planning, it must be related to the physical resource base for crop production. This has been done, in relation to three key factors: climate, soils, and vegetation. Known measurements, such as those on rainfall, levels of insolation, and length of growing period, have been applied.

Access to markets

Access to wholesale markets is a precondition for a market-driven system to be viable. About 60% of IITA's mandate area in West Africa, for example, was assessed as having a good market access. This is because the major centers of coastal countries in the region are well connected by a network of roads, as well as seaports providing access for agricultural marketing. Also, because tree crops

Finding out from farmers in southwestern Nigeria about their crops and practices

* In this study, a "cash" crop was defined as any crop, including food crops, where the major part of its production is sold for cash in the market. Traditionally, the use of cash crop has been associated with nonfood "export" crops, such as cotton or tobacco.

that can be sold (cocoa, coffee, oil palm, rubber) are grown, additional funds can be attracted to maintain the roads. The relative prosperity of this subregion indicates the potential for the remaining 40% of the area where poor access to markets has hindered development, also posing a challenge to policy makers.

In areas where the transport systems are adequate but market-driven intensification has not yet occurred, research and policy can weigh in favor of profitable cash crops, such as maize and cassava, in which many countries are close to self-sufficiency. But an expansion in marketable surplus will likely need to be supported by improved processing technologies. Tree crops, such as cocoa and oil palm, can also play a role in the more humid parts. But it would require higher yields and improved processing techniques to enable those crops to remain profitable under current conditions of oversupply in the world market. There are indications that cassava is progressively replacing such tree crops, but improved processing technology would still be needed to realize its full potential as a cash crop. The ecological implications of cassava replacing tree crops would still need to be addressed. This is being attempted through the introduction of alley farming, which involves the growing of trees and food crops simultaneously.

Where transport systems are poor and market-driven intensification is unlikely, the challenge will be to enable food production to keep pace with population growth, and to prevent degradation of the resource base. This twin challenge indicates the need for soil improvements, reduction of pests and diseases, and expansion of crops like cassava, which give a high calorie production under relatively low soil fertility and low levels of purchased inputs.

On average, 42% of the total area studied was found to have at least one profitable major cash crop. For example, the northern Guinea savanna of Nigeria produces a profitable surplus in maize for the market, which has been the driving force behind the intensification of its agriculture. This emphasizes the comparative advantage that an improved technology can provide, to the extent of making a crop dominant, especially where the environment is highly suitable for the crop.

Some insights gained

Data gathered in this characterization effort have given several valuable insights. While some of these are mentioned or discussed within the accompanying article, here are a few others that might be of interest:

- In West Africa, population-driven agricultural systems occupy 66.5% of the area, while market-driven systems occupy the other 33.5% (see Figure below).
- Three countries—Nigeria (40%), Côte d'Ivoire (28%), and Ghana (12%)—together account for 80% of the area in West Africa where the systems are market driven.
- New arable land is still available for cultivation in 84% of areas where land-use intensity is low, 81% of areas where it is moderate, and 35% of areas where it is high. For this study, land-use intensity was defined as low when the fallow period was 2 times or more the period of cultivation, as moderate when the fallow period approximately equalled the period of cultivation, and as high when the fallow period was half or less of the period of cultivation.

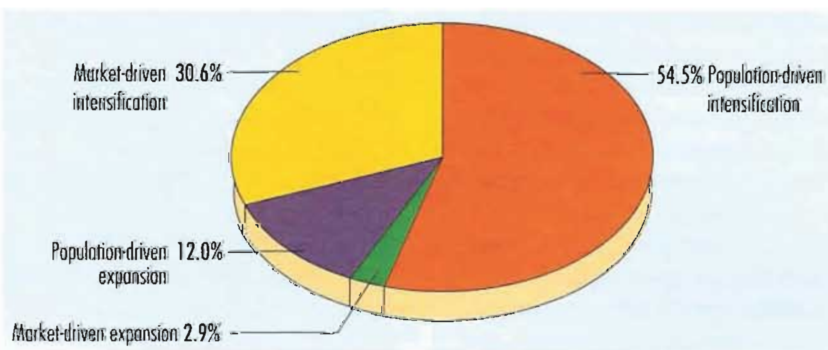
  Thus, in this region, a high level of land use does not still mean that the limit of land availability has been reached. Land-use intensity has been limited by tenure considerations, and by lack of adequate transport and other socioeconomic infrastructure.
- Areas of market-driven expansion or intensification have decreased where population density has increased, showing that increase of population density is not a determinant for market-driven intensification.
- Areas with population-driven agricultural systems depend mainly on natural resources to sustain agriculture. The most appropriate technologies here are those that economize on purchased inputs and family labor. In market-driven areas, farmers are likely to adopt technologies that will demand purchased inputs and hired labor because of the substantial cash they will gain from selling their agricultural produce. Pressure on natural resources is thus likely to be less intense in market-driven than in population-driven areas.

Ecological implications

The implications of a crop-dominant technology on resource management and on the agroecology as a whole need to be considered as well. When a new crop is introduced to areas where it is not traditionally grown, it may result in drastic changes in the agricultural system, especially where the crop has a distinct comparative advantage. This has been shown repeatedly: by the introduction of maize and cassava across agroecological zones, of soybean in northern Nigeria, and of other legumes as a short-duration cover crop in several parts of West Africa.

In areas where market-driven intensification leads to the spread of one dominant crop, the issue of sustainability can be addressed by providing a greater role for legumes and crop-livestock interactions in the

Land-use pattern for agriculture in West Africa, as determined by population pressure and market forces



system. Crops can also supplement each other. For example, cotton is a leading cash crop in the northen Guinea savanna of Benin, Cameroon, and Côte d'Ivoire, but it has also supported the spread of maize through improved input supply and marketing facilities.

The challenge overall is to ensure that improved technologies can offer the farmer some "visible" gain, as well as help address the issue of resource depletion. The main gains to farmers still need to be emphasized in terms, for example, of more food, added income, better health and nutrition, or less labor, while the technologies so promoted also do something to protect and preserve the environment. There are success stories of this kind (alley farming, the use of mucuna against the imperata weed, to name two examples) and lessons learned from them should be applied to other new technologies.

In summary, areas with a high land-use intensity have the highest need for resource management technologies. But as conditions there cause a favorable disposition toward change, results can be achieved fairly quickly. In much of West Africa, however, land use is only moderate (see box). Here, the farmers are not yet sensitive to the potential for resource degradation. The challenge to develop suitable technologies would be particularly important here, as would the additional challenge to present them in terms that can appeal to the farmers.

Need to revalidate

The time frame in which this characterization was carried out must also be recognized. Characterization is, after all, a continuous process, involving updating or upgrading of information, and of the understanding that flows from such information. Since the situation is dynamic, solutions that are designed must have in-built mechanisms for revalidation. In order to confirm the trends observed so far, efforts at meso- and microcharacterization are already in progress at several sites, with national program scientists playing a key role.

TECHNOLOGY GENERATION

Fallow systems for sustainable farming

Farming in West and Central Africa has for many years been pushing into areas that were once considered difficult—poor soils, thick forest cover, remoteness, or other former deterrents to cultivation. At the same time farmers have been forced to shorten the fallow period and to coax bigger harvests from the soil by increasing the use of fertilizer, where possible, and other inputs. Growing numbers of people to feed in the farming communities and the towns beyond have created the pressure to extend and intensify cultivation.

At the same time in some farming areas, population numbers are decreasing because of better job opportunities elsewhere, or simply because of the difficulty in providing enough food or income from local resources. In such areas of decreasing population density, the land can become degraded because there are too few farmers to practice sustainable cultivation methods. Lack of labor to clear land that has been under fallow results in the repeated use of cropped fields, the neglect of tasks to maintain that land, and the abandonment of restorative fallowing.

Agricultural scientists as well as farmers are concerned that croplands which are subjected to such worsening pressures cannot sustain their capacity to produce food. Croplands must be allowed to rest and build up the soil's organic matter, which fuels the biological cycles in the soil that in turn determine its fertility. Without such a fallow period, the soil is gradually impoverished which encourages weeds, insect pests, and diseases to proliferate. Crops then grow poorly with low yields.

Quest

The key element in this dynamic is the quality of soil organic matter, which declines under unremitting cropping. Farmers need to be able to avoid soil degradation while increasing their productivity—hence, the quest for technologies to achieve "sustainability" in farming, a vital goal of current agricultural research in tropical Africa.

In earlier times, agriculture in West and Central Africa was sustainable because farmers would shift from a cultivated site to an uncultivated one before severe decline could set in, leaving the fields to recoup their nutrient losses under natural regrowth. Since most farmers today face decreasing options, researchers are turning to systems of cultivated or managed fallows to provide technologies for sustainable farming.

Proper management of selected fallow species can return organic matter to the soil, suppress weeds, reduce erosion, and contribute to sustenance of soil fertility. Legumes are particularly useful because they add nitrogen to soils and endow the soil with organic matter from their abundant biomass.

Short-term experiments have confirmed the value of legumes (both herbaceous and tree varieties) in preventing soil degradation. In spite of years of work on the main components of sustainable crop production, however, research has yet to show how long the different types of improved, managed fallow systems might sustain farming—or whether any of the systems would be economically attractive for farmers.

Answers

The answers to those kinds of questions can only come from decade-long experimentation, especially if agroforestry systems are the subject of research. Long-term trials which investigate the effects of various fallow systems on soil fertility—i.e., its organic matter content and quality—require controlled conditions which are best provided by researcher-managed, on-station trials.

IITA began a long-term experiment on the productivity and sustainability of improved, managed fallow systems in 1989, on 8.5 hectares within the IITA headquarters site that had been covered by secondary forest growth for more than 23 years. Located within the "derived savanna" zone (sometimes called the forest-savanna transition or "forest-savanna mosaic"), between the humid forest and moist savanna zones of West and Central Africa, the area receives an annual average of 1,250 millimeters of rain, with two peaks in rainfall distribution that occur in June and September. The dry season falls between November and March. Soil type of the experimental site is mainly alfisol.

The intention is to determine whether IITA's most promising technologies could be the basis for a system that would enable a farmer to cultivate the same piece of land intensively for a long time, without impairing the fertility of that land. One of IITA's chief aims is to create a managed fallow system, which conserves or replenishes organic matter in the soil, to replace the "bush" fallow or natural regrowth of traditional "shifting cultivation", which depends on perpetual availability of uncultivated land for crop production.

The two managed fallows in the study are "alley cropping", with hedgerows of a nitrogen-fixing tree legume which improves the soil with its prunings, and a ground cover or "live mulch", which continuously supplies the soil with organic matter through its litterfall. Alley cropping sustains the fertility of farmlands by approximating the forest ecosystem within the cropping system. The hedgerows provide the restorative processes of a fallow and help prevent soil erosion, while the farm can produce food, fodder, and fuelwood on a continuous basis. (See related article in *IITA Annual Report 1992*.) In the live-mulch system, an herbaceous legume maintains a permanent ground cover which suppresses weeds and reduces soil erosion, besides replenishing soil organic matter and nutrients.

Fixes

Both systems add nutrients to the plant/soil system through their ability to "fix" atmospheric nitrogen in the soil and to recover nutrients from deep soil layers, which are normally inaccessible to the shallower roots of food crops. The nutrients are delivered to the topsoil by the pruned or fallen leaves and stems of the fallow species which are broken down by soil fauna and decomposed and mineralized by soil microorganisms. Hence, a vital part of the system is the microenvironment which the fallow species provides in the soil for fauna such as earthworms and microarthropods, whose activity determines the rate at which litter can be transformed into the stuff of fertility.

The main objectives of the study are to:

- Compare the managed-fallowing technologies of alley cropping (*Leucaena leucocephala* as the hedgerow species) and a ground cover (*Pueraria phaseoloides*) with natural regrowth (bush fallows) and with the existing secondary forest.
- Investigate the effect of fallowing on sustenance of crop production (maize and cassava, the dominant intercropping combination in the zone).
- Evaluate the cost effectiveness of the different systems.

Each of the 3 fallow systems has been cropped, since 1989, at different rates, following the prevalent range of cropping intensities among farmers in the zone: continuous cropping (100% utilization of the land), and cropping after 1, 2, and 3 years of fallow period (being 50%, 33%, and 25% utilization, respectively). A full crop/fallow cycle in this experiment is thus 4 years. The fallow species have been continuously maintained, being managed (weeded or pruned) to prevent competition with the crops.

Part of the experimental area is undisturbed forest which serves as a control plot, against which to measure the performances of the managed fallows.

Each plot in the experimental treatments measures 12 by 20 meters, a typical size among smallholder or subsistence farming families in areas of high demographic pressure on the land. Following normal local practice, no agricultural chemicals have been introduced and tools have been limited to simple hoes and other implements. At the beginning of each cropping season, the fallow vegetation in all treatments has been slashed and the dried plant residue

Precision drilling in *Pueraria* fallow plot, to install tensiometer for measuring soil water tension; maize cropping and undisturbed forest in background.

Konrad Vielhauer

burned before crops have been planted, in accordance with traditional practice.

First results

Preliminary results from the long-term study were summarized in 1993, some 4 years (being 1 full crop/fallow cycle) after the trials began. Continuous concurrent with the fallow treatments cropping under low inputs (primarily labor), as might be expected, reduced crop yields, increased weed pressure, and impoverished the soils over the years in all fallows, particularly the natural regrowth. Conversely, the longer the fallow period, the better were maize yields, the smaller the effects of weed pressure, and the greater the activity of earthworms.

Much further study of the great range of data already collected, and those to be collected in the coming years, will determine which of the 3 fallow systems will emerge as the front runner. Each of the systems has specific advantages in different respects, across the range of conditions being measured in the study.

Nonetheless, initial analyses in several important respects show that the *Pueraria* live-mulch system produces superior results:

- best maize yield after one year of fallowing (see figure 1)
- lowest effects of weed pressure on maize yields
- highest earthworm activity and best organic-matter content of worm casts
- greatest direct contributions of organic-matter fractions to topsoil
- most effective in taking water from deep soil layers, and in redistributing the soluble nutrients to the topsoil through litterfall.

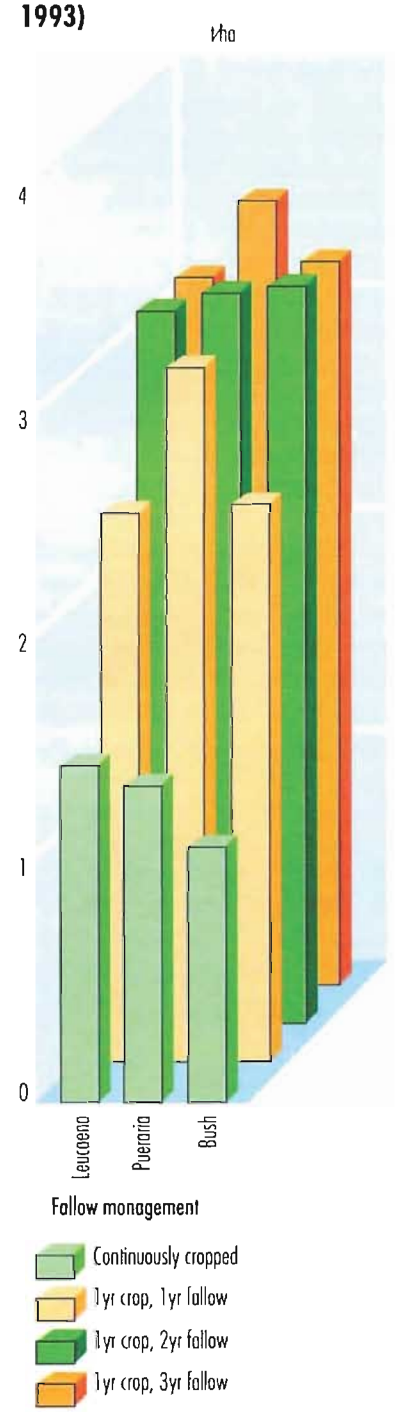
Looking at crop production, maize yields in plots under continuous cultivation fell sharply in the natural regrowth or bush fallow trials, but showed more stability in trials with the two managed fallows. Maize yields stabilized in all treatments after 2 years of fallowing, irrespective of cropping intensity. Cassava yields were highest in the natural regrowth, however, and lowest with live mulch.

With weeds, the bush fallows consistently fostered a higher weed pressure and concomitant yield loss in continuously cropped plots than did the alley cropping and live mulch systems. Weed density was very high in alley cropping treatments after a fallow period, possibly because of volunteer *Leucaena* seedlings.

Worms and water

Earthworm activity, measured in production of worm casts on top of the soil, contributes to soil fertility and gives a good indication of how favorable is the soil environment for such faunal activity and plant growth. Worms move soil with nutritionally valuable fractions in their casts from deep layers to the surface. Also, worm tunnels help increase the flow of water to plant roots. Fallow systems with no or little tillage, few chemical inputs, and much organic matter from mulching encourage casting and, in turn, are nourished by its benefits.

1. Effect of fallow management and cropping intensity on maize grain yield in plots weeded twice (IITA, 1993)



Earthworm activity in all the fallow systems, during 1992, did not attain the same level of cast production as that of the control plot of undisturbed forest, until 4 months into the cropping season. Thereafter, the live mulch showed the most favorable environment for worms, followed by alley cropping. Worm casting under natural regrowth never attained the level of that in the forest. (See figure 2, on page 19.)

After a 3-year fallow period, however, the undisturbed forest remained the most favorable environment for earthworms throughout the cropping season. Earthworms produced fewer casts in each of the 3 fallow treatments than in the forest.

Hence, a long fallow period does not appear to enhance earthworm activity; while continuous cropping, which incorporates an improved fallow system (live mulch or alley cropping), appears to promote earthworm activity. Casting in alley plots was most vigorous close to the *Leucaena* hedgerows, and tapered off with increasing distance from them.

In water uptake and distribution in the soil, natural regrowth and alley cropping did not show as good results as did live mulch, throughout the 1993 cropping season. Having relatively less capacity for water uptake, the natural regrowth and alley cropping systems foster greater leaching of soil nutrients during the rainy season.

In soil with a structure that favors water infiltration, the *Pueraria* live

(continued on page 19)

TECHNOLOGY DEPLOYMENT

How African programs help each other to use leguminous cover crops

The challenge in African agriculture is to raise productivity of small-scale farmers in a diverse range of environments—less favorable, more heterogenous environments than those already exploited with high-yielding varieties and other "green revolution" types of technologies.

In IITA's experience, the most effective strategy is to address the specific biophysical, socioeconomic needs of farmers in target areas. In such a strategic approach to research on area-specific problems, the question arises: who has the comparative advantage, international centers or national programs?

The evolution of the Collaborative Group on Maize-Based Systems Research (COMBS), comprising scientists from national institutes who work with IITA agronomists and economists, provides a positive example of how the two types of program can complement each other's advantages and create effective solutions to specific problems.

The COMBS group consists of 10 teams of scientists from IITA and 6 countries in West and Central Africa:

- Bénin (*Institut national des recherches agricoles du Bénin* [INRAB], Cotonou)
- Cameroon (*Institut de recherche agronomique* [IRA], Bamenda and Garoua stations)
- Côte d'Ivoire (*Institut des savanes*, Bouake)
- Ghana (Crops Research Institute [CRI]: Kumasi and Nyankpala stations)
- Nigeria (Institute for Agricultural Research, Samaru; Institute for Agricultural Research and Training, Ibadan)
- Zaire (*Service national de la recherche appliquée et vulgarisation*, Kinsasha)

COMBS develops ways to apply legume-based technologies, which combat crop production constraints, through improved on-farm research approaches and methods. Both technical and "process" aspects of the task are interdependent—the technologies and their application are developed under farm conditions with the help of farmers, whose insights in turn may lead to modifications which better address their needs and which help sharpen the research focus.

On-farm first

COMBS began in 1989 as a group of researchers in resource and crop management issues—national program scientists who were collaborating with IITA in testing of technologies with farmers for increased maize yields. The main objective was to exchange information about on-farm research methods so that group members could improve their own practices and research results.

The chief research issues among the group at the time reflected the worst common constraints in maize production systems: how to maintain soil fertility and control weeds. The single most promising lead was the use of leguminous cover crops in various cropping patterns with food crops.

The researchers recognized that each of their institutional bases was strong enough to conduct its own program on local, site-specific factors of a problem, so that each institutional team would conduct independent research on the common themes.

The collaboration essentially consists in development of research approaches, methodologies, and technologies through periodic meetings and mutual training experiences.

Since 1989, the group has met each year in a different country. Each host institute has presented a relevant part of its program for comparative purposes, to generate constructive discussions.

At the fourth COMBS meeting during 1992, for example, the IRA/Garoua hosts presented a range of legume-based technologies, native as well as introduced species, which they had developed to the multiplication stage. Participants from IRA/Maroua intrigued the group with a "minikit" technique for farmer-managed testing, which involves single treatments with very little supervision by extension agents.

In 1993, the host institute in Nigeria (the National Root Crops Research Institute) and IITA conducted a training exercise in on-farm research and technological applications, to address needs expressed by members of COMBS and a sister network of root crop researchers.

COMBS members have also organized inter-institute visits to demonstrate use of new, effective research techniques. The two Ghana teams (CRI/Kumasi and Nyankpala) visited Benin during 1991 to acquaint themselves with the mucuna technology and the on-farm methodology firsthand. They subsequently organized testing of mucuna-improved fallowing with farmers in Ghana's forest zone. A Cameroonian team from IRA/Maroua also made a special visit to Benin, in 1993, which helped them to reorient their on-farm testing activities to include farmer participation and to set up testing of mucuna in Cameroon's northern Guinea savanna.

Benin's bonanza

Benin's INRAB team had since 1987 put farmers in the forefront of the technology design process. With IITA and the Netherlands's Royal Tropical Institute (KIT), INRAB had organized farmer groups to select and experiment with several different options to improve soil fertility in maize cropping systems.

The researcher/farmer discussion groups opened the way to the farmers' whole-hearted cooperation.

M. N. Versteeg

Benin: green gold

The results broke new ground, as the farmers discovered a key advantage to the mucuna option which had not figured explicitly in the researchers' design. The farmers noticed how mucuna suppressed "speargrass" (*Imperata cylindrica*), a scourge which can thoroughly infest even small plots, forcing subsistence farmers to abandon them. The farmers also appreciated how mucuna improved maize yields of crops planted the following season. The mucuna technology thus became the most popular option.

In 1990 the extension service picked up the mucuna technology, with support from the Sasakawa/Global 2000 agricultural development project, to promote it among farmers in the southern region of the country for its dual benefits. After 3 years of promotion, it has been reported that more than 3000 farmers in the 5 southern provinces were using mucuna, either as a sole crop to control speargrass or as an intercrop to improve soil fertility.

Feasibility

The group realized that legume-based technologies would not be adopted unless they could be demonstrated to be worth their cost to farmers, in terms of soil fertility and weed-suppressing benefits and other possibilities, such as food uses and erosion control, among others.

The soil fertility benefit of an herbaceous legume might be equivalent to 1 50-kilogram bag of urea per hectare for the following season's crop. On the other hand, the effectiveness of the technology as a weed suppressant would depend on the nature of the weed problem and on agronomic factors. Before adopting any particular technology, the farmer would have to weigh its various benefits against the loss of cropping area occupied by the cover crop for that season.

Women farmers, who cultivate gardens that supply their household's daily food needs, might be particularly reluctant to give up production area for agronomic purposes, without a concomitant food production benefit. Potential food uses of legumes could usefully figure in the research strategy for promotion of such technologies.

COMBS researchers realized that they must be able to characterize their target area very carefully, in order to make an effective selection of leguminous technology for local conditions. For that reason, matching of technologies to conditions in farmers' environments became COMBS's guiding principle for technology testing with farmers.

COMBS therefore developed a guide for researchers and extension agents to use in matching technologies with the conditions or requirements of the farm. "Improvement of soil fertility and weed suppression through legume-based technologies" was published in 1993 as *IITA Research Guide 48*.

The guide offers a 4-step method for selecting a leguminous cover crop appropriate to the specific environmental conditions of a farm:

1. Definition of 21 criteria (agroecological, socioeconomic, and agronomic) which compose the characterization of the target area and application of the technology.
2. Ecological and socioeconomic characterization of the target area and the farming systems within it.
3. Agronomic and economic characterization of the legume-based technologies.
4. Identification of the most appropriate leguminous cropping system for the improvement of soil fertility and weed suppression in the target area.

Pinpointing the right technology

COMBS has also developed a "decision-support" system called LEXSYS—Legume Expert System—for integration of herbaceous legumes into farming systems. Published in 1993 as a handbook and a set of software files (FoxPro 2.0) on two 3.5-inch diskettes, LEXSYS (version 1.0) contains information on more than 100 tropical legume species from all over the world. COMBS researchers contributed information from scientific literature on leguminous crops which they had collected from their own institutes and others in the region.

The information is accessible in a practical, field-oriented format. It will be reissued periodically in updated versions to reflect new research results. LEXSYS is intended to be used as a tool in identifying promising technologies for field-testing with the contributory participation of farmers.

Apart from the publication of *IITA Research Guide 48* and LEXSYS 1.0, COMBS's accomplishments include tangible improvements in the research programs of member institutes.

The group offers a collaborative mechanism, which permits members to observe and comment on each others' on-farm research practices and together evolve improvements for specific requirements in each others' agenda. The value of each member's experience can be shared and multiplied among all, often resulting in substantial savings as greater efficiencies are achieved.

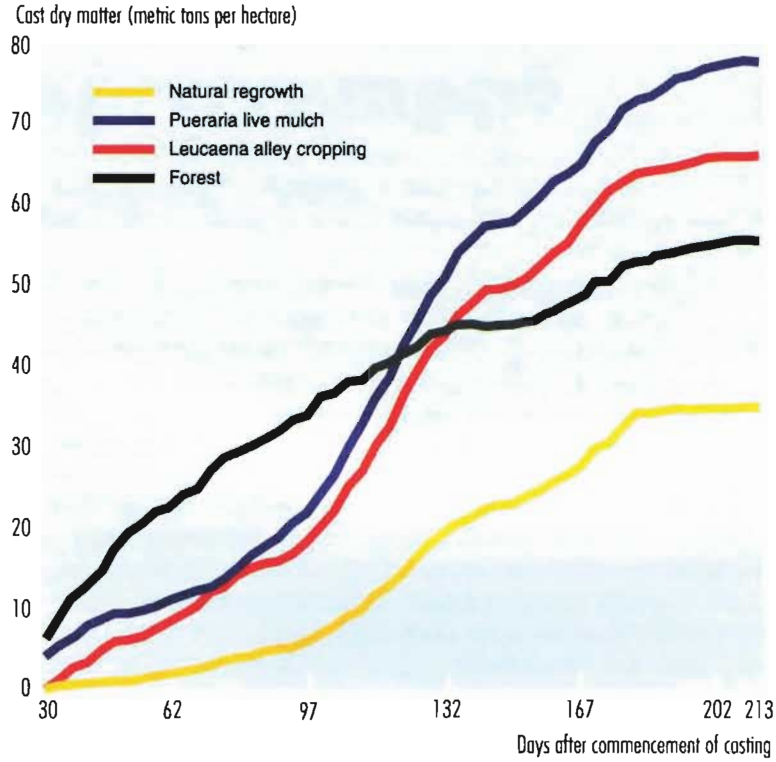
The group's innovative interactions have stimulated the IITA team to develop a methodological approach for targeting technologies to specific areas, which takes into account the dynamic nature of farming systems.

An understanding of the forces which drive changes in farm production, primarily demographic or market factors, is essential for accuracy in characterization of a problem and in selection of the right technology for a solution. Real understanding is especially important in the heterogenous environments of the COMBS region, where production systems are evolving from extensive to increasingly intensive farming. (See article on "macrocharacterization" in this section.)

Above all, COMBS's activities have attested to the value of the farmer's contribution in agricultural research. The farmer's practical knowledge of crop production problems and of the limits of his or her resource base is a key tool for the researcher. Farmer participatory research has, in the COMBS experience, opened the way to increases in research-based production gains.

Fallow systems *(continued from page 16)*

2. Earthworm cast production under different managed-fallow systems (cumulative, 1992)



mulch system facilitates water infiltration into the soil more than do the other two fallows. A dense layer of decaying plant residue covers the soil surface which helps trap runoff and minimizes erosion. Also, *Pueraria* roots reach deeply into the soil, enabling it to absorb enough water from the subsoil to meet its transpiration needs. Water can permeate the soil through the channels left by those roots, after they have died off.

The basic process studies of the dynamics of soil water and nutrients are being conducted by a special project of the German government agency for technical collaboration, GTZ. Within the project during the next several years, the nutrient content of soil, soil water, and plants will be analysed, the nitrogen contribution of legumes will be quantified, root distribution and densities will be measured, litterfall and prunings will be assessed, soil faunal species monitored, and many related investigations performed.

The whole picture of the relative effectiveness and efficiencies of alternative cropping systems will gradually be assembled under the general project described in these pages: IITA's resource management research project known as "Determinants of sustainability in cropping systems" and funded by the core budget. The entire project calls on interdisciplinary contributions from specialists in the crop sciences, plant health management, and social sciences. As further knowledge accumulates about promising technologies for sustainable agriculture, colleagues from national programs will become involved in testing and adapting them for local application. (See the article on "Technology Deployment" on page 17 which describes such a process.)

Plantains can be grown perennially in the field, research shows

IITA scientists have shown, as a result of decade-long research, that plantain can be grown as a perennial crop, in a sustainable production system under certain conditions. The impact on production is potentially great, as field production in commercial quantities has been limited and most supplies of plantain come from backyard gardens.

These studies have a history. It was observed early in IITA's research that plantains performed extremely well in home gardens (where soils are generally rich in organic matter, mainly because of household refuse), but not in the fields, especially in the highly weathered soils of West and Central Africa. Rapid yield declines were—and still are—common in open fields after 1–2 years of cultivation, even with liberal applications of inorganic fertilizer.

The causes for this rapid yield decline are complex. The root system of plantain is relatively shallow. In addition, pests build up because plantain is a long-duration crop, with a production cycle of 12–18 months. The plants can easily fall down under strong winds because of poor root development, combined with root damage. Another contributing factor is "high mat," a condition where the base of the plants tends to grow out of the soil, as they anchor poorly. The plants ratoon or grow shoots slowly, which lengthens the production cycle.

IITA scientists have been working on all these problems. Early in the 1980s they started by studying the effects of fertilizer and mulch, since mulching is a means of improving soil organic matter to sustain plantain productivity. Early research showed that yield decline can be arrested by mulching from an external source, such as elephant grass (*Pennisetum purpureum*), and that plantain only responded to applied fertilizer in combination with mulch. Mulching enhanced root and sucker growth and reduced the high mat effect, thus slowing the yield decline.

But mulch input from external sources requires intensive labor, as well as additional land on which to grow the mulch material, so it was not found economically viable. Alley cropping offered an attractive option, since the hedgerow trees and shrubs could serve as the source of mulch for the plantain, which would be be grown in the alleys.

No longer confined to backyard gardens: a sustainable system for perennial plantain production

Ezgu Rondo

Plantain yields in alley cropping were lower by between 19 and 41% than in the system with external mulch, but there were some compensatory advantages. For example, *Acioa* (now *Dactyladenia*) *barteri*, a locally grown tree, offered the best results: in return for a yield decline of 19% compared with the control treatment (external mulch), *Dactyladenia* offered superior weed suppression and soil improvement because of its mulch.

Another long-term trial began in 1987 which specifically studied the perennial yield potential of plantains. The bush was cleared manually after a fallow. The residue was not burnt, as is traditionally done. In hedgerows that were spaced 3 meters apart between plantain rows, the natural shrub and tree species were allowed to grow. This provided a natural, multispecies alley cropping system.

A 1992 survey identified more than 120 plant species in such 5-year-old hedgerows. After 6 years of plantain cultivation in the alleys, there was no evidence of yield decline, suggesting that the system can maintain productivity over extended cultivation periods and conserve plant diversity for future fallow periods.

In a related trial, annual and perennial cultivation of plantains were compared in a multispecies alley cropping system to test the hypothesis that annual replanting might help overcome rapid yield decline in plantains. In the annual system, the best sucker (or follower) is replanted after the mother plant is harvested. In the perennial system, it is left to ratoon. Our results show that perennial cultivation is significantly more productive (4-year mean yields of 20 tonnes per hectare, against 15 tonnes for annual cultivation). Perennial cultivation thus appears to be more profitable, with yields that can be sustained under appropriate practices of crop management.

The growing cycle of plantains has already been shortened with improved hybrids developed by IITA scientists early in the 1990s. Studies continue on many related facets.

Crop Improvement

Highlights 1993

Research Delivery

Three cassava varieties from IITA were officially released in Ghana during 1993. They are IITA clones and were given local names—Abasa Fitta for clone #(2)1425, Afisiafi for 30572, and Gblemo Duade for 50395. The official release was the culmination of 5 years of extensive and critical evaluation at 8 locations, which encompass the major agroecological zones in Ghana.

Selection and evaluation of the clones had originally begun at IITA early in the 1970s. The period from 1981 to 1987 was one of maintenance, multiplication, announcement of availability, and—finally—negotiations with two quarantine authorities, during 1987, for transfer of fresh cuttings to Ghana, where the final selection process commenced in 1988.

The foregoing details show why long lead times and tenacity in commitment are a requirement in crop improvement research. Research should, of course, be well-focused with the clear intention of achieving impact. But that impact cannot happen overnight—even now, following the official release of the varieties in Ghana, rapid multiplication schemes must function well if they are to reach farmers on the hoped-for large scale.

Fourteen improved tropical *Musa* plantain hybrids (TMPx), which are resistant to the fungal disease of black sigatoka, were registered in the public domain in *HortScience* 28(9), pages 957–959 (1993). (See story in these pages.) Currently hybrids are being evaluated in collaboration with national, regional, and international institutes in 13 countries. Such a rate of progress, with a crop widely considered to be intractable to genetic improvement by classical methods, has been exceedingly rapid.

Seed of IITA maize, soybean, and cowpea varieties were available in the commercial sector in 1993. Each of the three seed companies operating in Nigeria (Pioneer Hi-bred, UTC, and UAC) officially announced the IITA varieties in their catalogues, either under their own name or that of IITA, directly. Examples of maize include Pioneer's hybrid varieties Oba Super 1 (IITA ref. 8321-18), Oba Super 2 (8644-27), and New Kaduna (8505-4); UAC's Mega Maize Services MM-1 to -5, which are IITA open-pollinated, steak-resistant varieties. Two of UAC's open-pollinated varieties are resistant to downy mildew. UTC has produced the IITA open-pollinated variety for the midaltitudes, TZM-SR-W, and two hybrids.

Of soybean, both UAC and Pioneer advertised TGx 536-02D in their catalogues. Of cowpea, UAC had the IITA varieties ITA 2246-02D, while Pioneer had IT82D-716 and IT84S-2246.

In Mozambique, the national seed company SEMOC has utilized IITA maize germplasm adapted to the lowland tropics. Of 4,000 metric tons of maize seed which SEMOC produced during 1993, some 3,000 metric tons originated from the IITA open-pollinated variety DMR-ESR-W, which was given the local name Matuba. Harare-based CIMMYT staff assisted SEMOC to improve the level of streak resistance.

R&D

Breeding for *Striga* resistance recorded outstanding performance in multilocational trials of 9022-13 STR under artificially infested conditons. (See story on page 35.) The open-pollinated breeding program for *Striga*-resistance made good progress, although the levels of resistance available do not yet match those of 9022-13, the best hybrid.

Resistance to the cassava green mite has been improved in many cassava lines currently under evaluation for advanced yield trials. Seed populations have been distributed to national programs (10 during 1992, 5 during 1993). Sources of resistance include new lines from Latin America, wild *Manihot* species (especially *M. tristis*), and some African landraces.

Soybean acceptance in Nigeria was amply illustrated at the workshop held at IITA mid-year on small-scale and industrial-level processing. (See story on page 23.) The workshop clearly demonstrated that soybean had become a crop for which demand currently exceeded supply.

Improvement of farmers' local cowpea varieties made good progress during 1993. (See story on page 27.) Excellent farm-level impact is expected in a few years' time.

Sustainable, perennial production of plantain was demonstrated after 7 years of trials at IITA's High Rainfall Station, at Onne, as the result of application of adequate crop and resource management practices. (See story on page 20.)

The effectiveness of promiscuous nodulation of soybean in farmers' fields was confirmed during 1993.

Building on the results of field trials in 1992, a trial was conducted to examine the yield, nodulation, and nitrogen uptake of soybeans under 3 soil-nitrogen treatments: applied inorganic nitrogen, a seed-applied inoculum of *Bradyrhizobium*, and uninoculated seed whose only supply of mineral nitrogen was the soil. Of the 19 test sites, 18 were in farmers' fields in Nigeria's main soybean-growing areas, in the lowland savanna and midaltitude agroecological zones.

The key finding was that the soybean yield performance was similar in all treatments. Promiscuous nodulation using a subset of cowpea rhizobia had occurred.

IITA places improved plantain hybrids in the public domain

During 1993, IITA made available to users worldwide published information on 14 improved tropical plantain hybrids it had developed and tested over the past several years. These hybrids, highly resistant to the devastating fungal disease, black sigatoka (discussed more fully in our *Annual Report 1992*), are now in IITA-assisted trials in 12 countries of the tropical world, which include 9 countries in sub-Saharan Africa. They will likely be released to farmers within the next few years.

Plantain (*Musa* spp.) is an extremely important food crop in sub-Saharan Africa, providing important nutrition (25% of carbohydrates, 10% of calorie intake) for many millions of consumers. It is also an important source of income for smallholder farmers, who produce them in compound or home gardens.

Pest and disease pressure on the crop has been increasing over the past 15 years or so, as production has intensified. Prominent among the constraints has been a leaf spot disease, black sigatoka, caused by the fungus *Mycosphaerella fijiensis* Morelet. First identified in Fiji, the disease was accidentally introduced into southern Africa in the 1970s and spread rapidly to many parts of the continent. It became so serious in the 1980s that several African governments encouraged IITA scientists to launch an urgent research campaign. Incorporation of durable host plant resistance to black sigatoka became the focal point of a genetic improvement program for *Musa*, initiated at IITA in 1987.

IITA scientists expected initially that it would take at least 10 years to develop such resistance. Previous research elsewhere had indicated that plantain would be notoriously intractable to genetic improvement by classical breeding methods. Given that background, the success in incorporating resistance to black sigatoka in improved plantain hybrids within a period of 6 years is especially notable.

That success was achieved by a combination of conventional and new approaches, including interspecific hybridization, ploidy manipulations, in vitro culture, field testing and selection, and studies into the nature of the *Musa* genome, which yielded new insights and information for exploitation in a breeding program. Some of the new insights in *Musa* genetics may now be applied to solve other constraints in plantain production.

Traits of improved hybrids

The placing of 14 improved plantain hybrids in the public domain was done through publication of their agronomic traits in *HortScience* 28(9): 957–959. All those hybrids had appreciably higher levels of black sigatoka resistance than their susceptible plantain parents.

The agronomic performance of the improved hybrids was superior to their fungicide-treated plantain parents on a number of traits, with the yield potential of the best two higher by 92% and 62%. When adjustments were made to provide a basis of comparison for no chemical control, those differences in yield potential rose to 224% and 174%.

Host response to black sigatoka was based on slower or delayed disease development. When the disease develops more slowly, reduced leaf spot damage enables a larger leaf area to remain healthy during fruit filling time. This results in larger, heavier fruits, increasing yields.

Relative to their plantain parent, the improved hybrids had a short plant stature and a tall sucker (follower) at harvest, both of which are desirable traits. Most hybrids had fewer hands, but they generally had a higher number of fruits per bunch, which is an important component of yield. There were both more and larger fruits per bunch in the improved hybrids, due to their earlier flowering and greater filling period.

The improved hybrids develop one or two suckers freely, while further suckering is inhibited. Regulated suckering is highly desirable for perennial plantain production. Unlike their plantain parents, which are female fertile but male sterile, the hybrids are female and male fertile. This means they can be used as parents to produce secondary hybrids.

The hybrids also had a shorter production cycle (11 months, in place of the 13–18 months of traditional varieties). This is a valuable trait.

Hybrid 548-9 (at center; with parents) doubles the benefit/cost ratio

which can help avoid high seasonal fluctuations in supply and crop losses caused by periods of glut.

A cost-benefit assessment was made for using the improved hybrids to overcome black sigatoka, in place of chemical control. Farmers would need an investment of at least US $750 per hectare per year to provide chemical protection against black sigatoka. Taking into account price fluctuations during different market periods in rural southwestern Nigeria, host plant resistance had a comparative advantage over antifungal chemicals ranging from 5:1 to 10:1.

Advances in *Musa* genetics

In the process of developing the improved hybrids, IITA scientists have unraveled significant new information and considerably modified previously held views on *Musa* genetics. One such assumption was that genetic improvement of cultivated *Musa* depends entirely on diploid breeding, using related *Musa* species. In phenotypes obtained from crosses, IITA scientists identified both diploids and tetraploids. As a consequence, IITA scientists are able to improve plantain germplasm at other ploidy levels.

A second point demonstrated by this work is that plantain breeding can create more variability than expected, because there is new evidence that the triploid genome of the crop undergoes segregation even when its total set of chromosomes is transmitted to the tetraploid progenies. Tetraploid hybrids are of immediate interest as potential new cultivars.

As a result of other information generated by IITA research, the genetics of various traits of plantain is better understood. The new information is being used in further efforts to improve plantain.

Working with NARS

National programs have been active partners in the multilocational trials that are required to assess yield stability and durability of black sigatoka resistance across environments. Multilocational evaluation trials and advanced *Musa* yield trials were set up.

Both IITA and national agricultural research systems (NARS) contribute resources for the joint testing. IITA provides planting materials, field designs, data analysis, as well as individual and group training. Trials are monitored during frequent visits. NARS run the trials with their own budgets. This demonstrates commitment of both partners in ensuring the flow of research materials and in technology development based upon reliable information.

Technical assistance in the development of tissue culture laboratories has also been provided to national research institutions in Nigeria, to sustain institutional development. Tissue culture laboratories will play an important role in the distribution and multiplication of clean and improved planting materials of selected genotypes. These facilities can also be used for other crops that benefit from in vitro culture techniques.

Information exchange occurs frequently, through meetings and correspondence, as well as formal publications. A plantain and banana newsletter for Africa, *MusAfrica*, was initiated in 1993, and three issues were brought out during the year.

SOYBEAN IN NIGERIA

As crop's commercial success grows, researchers address linked problems

As Nigeria's soybean industry has grown, supply and demand have swung between extremes. Bottlenecks occur along the way from farmer's field to industrialist's plant to the marketplace. IITA, which has pioneered soybean research for African production since the 1970s, has kept up with developments with an eye to lending research support whenever useful or practicable.

Since soybean was introduced in Nigeria during the 1940s, consumer utilization has driven production. In like manner, at IITA postharvest utilization became a second pillar of the soybean research program, once the initial breeding problems were overcome.

Part of IITA's aim in applied soybean research has been to strengthen the work of researcher and consumer groups in Nigeria and other countries, such as Ghana and Malawi, which are promoting soybean production. From 1987 to 1993, through its soybean utilization project funded by the International Development Research Centre (IDRC) of Canada and the Japan International Cooperation Agency (JICA), IITA and collaborating researchers involved Nigerian soybean farmers, small-scale processing and consumer groups, together with industrial producers and consumers, in project activities and helped them to articulate their emerging interests and needs.

The project carried out baseline surveys, product development (particularly in food fortification), design and testing of processing technologies, followup surveys of impact assessment, and training of a wide range of target groups. The main Nigerian collaborators were the Institute for Agricultural Research and Training, the National Agricultural Extension Research Liaison Services, the National Cereals Research Institute, and the University of Nigeria at Nsukka.

Utilization research and promotion stressed soybean's advantages in household consumption and sought to train women and groups concerned with social welfare. Industries which process or utilize soybean grew to include vegetable oil, animal feeds, baby foods, snack foods, and beverages. In February 1991, the project identified 21 companies in Nigeria which used

Multicrop thresher: grain gains call for processing boost

soybean as an ingredient in its projects. By 1993 that number had more than doubled, to 50.

In July 1993, IITA held a workshop of small-scale and industrial soybean processors, which brought together the whole spectrum of producers from the cottage-industry to large-scale levels, as well as soybean growers. Production and marketing information gathered by the IDRC project was reviewed. Producers and processors exchanged views on development of soy-based food products and the associated equipment and machinery for their manufacture.

The processors' main message for producers was that they needed more grain of better quality than they could usually find. Growers replied that the shortfall in quantity and quality of supplies derived partly from lack of inputs—they complained that availability of single superphosphate fertilizer had been erratic.

Beyond that market gap, they had encountered less tractable problems: (a) shattering of mature pods in the fields before they could be harvested; (b) laboriousness of threshing; and (c) yield loss through *Cercospora* leaf spot disease. These are problems which researchers ***can*** tackle. IITA and collaborating scientists have worked on them for the past few years, with excellent results to date from field-testing which are described in the second half of this article.

Demand-driven surge

Despite the obstacles, the project surveys revealed that production had surged—more than a fivefold increase, for example, in 5 local government areas of eastern Benue state, from 1985 to 1989; and a fourfold increase in Kaduna state, from 1986 to 1990.

At the meeting it was clear that soybean, from a crop with no demand in the mid-1980s, had become a crop for which demand exceeded supply. The experience of the IDRC-sponsored project had affirmed the spread of soybean cultivation, consumption, and agroindustrial use in Nigera. The enthusiasm of the diverse stakeholders in soybean's future augured well for continued development.

How to replicate such a success story has been a tantalizing question for researchers who want to plan for similar projects elsewhere in West Africa. While Nigerian soybean has long benefited from a governmental ban on imports, that policy obviously could not have legislated the industry's growth. An industrial base had also not been essential in local developments, for the utilization project had successfully promoted small-scale processing.

Indeed, it appeared that development of utilization had created demand for soybean production. The expansion of the project to neighboring countries therefore seemed valid, if founded on utilization as the stimulator of demand-led production.

Linked problems

The shattering problem forces farmers to limit their soybean cultivation, to fields that their labor resources can harvest within the few days from when the pods are mature to when they shatter and scatter their grains. The shorter that time margin, the greater the constraint on farmers. The longer the interval before shattering, the larger the crop which farmers may plant without risk of loss.

IITA and Nigerian researchers have developed varieties that will shatter much less than the improved varieties available in 1987. The new varieties can remain in the field without shattering up to 10 days longer, which increases farmers' flexibility in management of their limited labor.

Grain gains As grains are saved through less loss from shattered pods, the increase adds to the threshing load. The problem with threshing is that it is physically very demanding and must be done quickly after harvesting, in the heat of the day, to avoid grain losses through discoloration and pod rot.

No bean breakage with the fail-safe flails

The problem has a gender dimension: women are generally more interested in planting soybean, yet they need to rely on men to do some of the onerous threshing.

IITA postharvest researchers have developed two threshers, depicted in these pages: one for hand operation (the "flail") and the other with a benzine-driven motor, the "multicrop thresher." Both have been tested in the savanna farmlands of Bauchi state in recent years.

The flail has usually been popular at first with women and children. Men have preferred the mechanical thresher, which saves much more time (up to 10 times) and eliminates the potential problem of damp rot of harvested but unthreshed soy plants. Its economic virtues seem eventually to win over women farmers as well, after they become accustomed to operating it.

Both the threshers reduce grain loses from harvesting and threshing operations. The multicrop thresher has rung up a 2% breakage rate, while the flail registers no breakage losses at all. Grain quality is further enhanced by virtual elimination of rot or mold damage. And the savings in labor are obvious and welcome.

Small but responsive

Soybean research at IITA has always been a small enterprise but, at the same time, remarkably effective in terms of meeting goals of production increases and quality improvement in target areas. IITA soybean scientists believe their successes have stemmed from their consistent concern about communication with farmers, consumers (mainly women who process soybeans into food), national program scientists, and industries (vegetable oil, livestock feed, and specialty food products).

That communication has allowed the scientists to identify the most important constraints in soybean production, marketing, and utilization; and then to focus their research on the emerging problems.

Breeding cassava for "safer" consumption, higher protein

How safe is cassava for human and animal consumption? Some 500 million people in the tropics, more than 200 million of whom are in sub-Saharan Africa, consume cassava regularly, without visible harmful effects. They thus provide empirical evidence of its "safety." Yet doubts persist (see box).

The doubts have some basis. Cassava is among many plant species that are cyanogenic—they possess the ability to generate cyanide—but in none of them is hydrogen cyanide (HCN, a lethal compound) produced directly or stored in the plant, at any stage of its growth. The plants produce substances (mainly glycosides, but in some cases lipids) that may break down and produce cyanide. In a natural balance, the plants also produce enzymes that are capable of breaking down the cyanogenic compounds so formed.

Those compounds and the enzymes that degrade them are always stored in separate compartments within plant cells or (as in sorghum) in different cells altogether. When the plant is damaged, the structural integrity of its cells is destroyed. As a result, cyanogenic compounds may break down, and hydrogen cyanide may be produced. This is what likely occurs in cassava, which produces two cyanogenic glycosides, linamarin and lotaustralin.

The compounds do not break down when cell walls are intact, but when cassava tissues are bruised and the cellular structures are disrupted, their breakdown can lead to the formation of hydrogen cyanide. The hydrogen cyanide, once it is produced, will dissipate in the air, since its boiling point is 25.7°C. Thus, in damaged plant tissues, such as in processed roots and leaves, one could find traces of hydrogen cyanide, as well as the two nonhydrolyzed cyanogenic glycosides. It is erroneous to refer to the concentrations of those three components in cassava as cyanide content. They are more accurately described as cyanogens, and their concentrations add up to the plant's *cyanogenic potential.*

That potential is subject to physiological processes, which occur slowly, as well as rapid and volatile biochemical processes. Scientists at IITA and elsewhere are engaged in an endeavor to understand those processes and to exploit them in reducing cassava's potential toxicity.

Processing

Scientific experiments have confirmed that any processing applied to cassava reduces its cyanogenic potential. Boiling cassava roots, considered minimal processing, reduces their cyanogenic potential by about half. Other processing methods can reduce it by more than 90%. This ability of the plant material to become less cyanogenic during processing is even more pronounced in cassava leaves, which have a cyanogenic potential 5 to 20 times greater than cassava roots. When the leaves are processed into foods, the cyanogenic potential is reduced considerably by pounding. After boiling for 15 to 30 minutes, it is virtually reduced to nil.

When the roots are boiled, the smaller the pieces of root and the larger the volume of water used, the greater is the reduction in the cyanogenic potential. Thus, grating cassava roots into a mash is an extremely useful step, as is pounding cassava leaves into a leaf meal.

Fermenting the mash or meal adds little. But fermenting whole storage roots in water (usually for 3–4 days) allows microorganisms to multiply, which then help cassava tissues to disintegrate the way grating or pounding does. The direct action of the fermentation agents on cyanogenic compounds or on cyanide itself cannot be excluded. The matter needs further study.

Cassava leaves have a much greater concentration of linamarase activity

Cassava poisoning rooted in poverty

Cases of cassava poisoning have been reported over the past two decades from various parts of Africa. But the risk of acute poisoning is often exaggerated, especially in reports in the mass media, which are often speculative. The best documented cases for chronic toxicity are for (1) nervous disorders in Nigeria; (2) goiter in Zaire and (3) "konzo", a neurological disorder recently identified in Mozambique, Tanzania, and Zaire.

These occurrences are rare. They are usually reported from remote areas where, during droughts or periods of public unrest, poverty and a paucity of other foods cause some people, especially the poor, to rely too heavily on cassava, and to eat it in inadequately processed forms. In such cases, availability of water and other foods (especially protein sources), as well as of cassava with higher protein content and reduced cyanogenic potential, would alleviate the problem, which seems primarily rooted in poverty.

than do cassava roots, which accounts for their superior ability to shed cyanogens during processing. Linamarase is the enzyme that breaks down linamarin to produce the toxic but volatile cyanide, subsequently lost in processing. Enhancing linamarase activity in cassava roots could thus be an effective way to remove cyanogens from them.

Selection and breeding

Breeding cassava for low cyanogenic potential has two major aspects: (1) selection of cassava varieties or populations with a low cyanogenic potential, so as to combine them with cassava varieties that offer other desirable traits; and (2) increasing the quantity and quality of root protein in cassava, so as to speed up the linamarase activity that helps in the removal of cyanogens from cassava roots.

Many years of screening have shown no cassava line in which cyanogenic potential was entirely absent, but that effort identified nearly 1000 lines in which levels of cyanogenic compounds are low (<1–5 mg HCN equivalent per 100 g fresh tissue). Of these, about 150 clones with very low cyanogenic levels (<1–2 mg/100 g) have been put into a food quality breeding population for 1994. These lines offer a good prospect for areas where cassava roots are eaten raw or simply after boiling. They will be crossed with other lines that offer desirable agronomic and nutritional traits (carotene content, for example).

Determining the cyanogenic levels has involved somewhat elaborate analytical procedures. A simple technique that can be applied to a large number of samples in the field is still being developed. As the cassava genotypes so identified will be used for different products, a parallel effort is now on to determine what HCN equivalent levels will be apt for each end use, given differences in processing.

In the last few years, the distribution of root cyanogenic potential among several collections of cassava genotypes has been investigated, and it was found that most varieties had a low rather than high cyanogenic potential. In doing so, it was found that the cyanogenic potential varies among different tissues of the root, between roots of the same plant, and between plants of the same variety in the same plot. Variability was greater between roots than between plants, and three-fold differences in cyanogenic potential of roots from the same plant were not uncommon. This emphasized the need to establish a proper procedure for sampling cassava roots, before a variety could be classified as having a low cyanogenic potential. A minimum of 3 roots per plant, 4 plants per plot, and 4 replications has been found efficient and cost effective in determining the cyanogenic potential of a variety in agronomic trials.

Within the same cassava genotype, the cyanogenic potential was found to be affected by time of planting: it was low with planting early in the rainy season and high with planting at the end of the rainy season. Water deficit is known to increase cyanogenic potential, but some new information that has emerged is being applied to study if the accumulation of cyanogenic glycosides within a cassava plant can be regulated.

Attempts to control cassava's cyanogenic potential by conventional breeding methods have met with limited success, possibly because there are multiple genes involved. Environmental factors further complicate this task, as just outlined. Biotechnological techniques may offer a promising route to manipulate this aspect.

Can that manipulation proceed so far as to produce noncyanogenic cassava? What influence will the total removal of cyanogens have on the plant's defence mechanisms against insects and diseases? The answers to those and other questions lie in long-term efforts (10 years at current estimates), which would involve inhibiting the biosynthesis of cyanogenic glycosides or diverting their accumulation to tissues in plant parts that are not eaten. Those efforts could also result in increased ability to routinely transform and regenerate the cassava plant.

In collaboration with an advanced laboratory in Denmark, IITA scientists have begun their attempt. IITA scientists also take active part in a Cassava Biotechnology Network, formed in 1988, with its Secretariat at Centro Internacional de Agricultura Tropical (CIAT), Colombia.

In the collaborative effort with Denmark, biochemical data available on key enzymes and genes for cyanogenesis are being used to develop accurate methods for screening cassava genotypes with a reduced ability to generate or store cyanogenic glycosides. One aim is to find some reliable molecular markers to aid selection for low cyanogenic potential. Such markers, which would identify traits whose genetic control may be closely linked to genes that control cyanogenesis, would offer a simple, rapid, and reliable way to select for this trait, relatively free of the environmental influences that have complicated field screening.

The second important avenue for lower cyanogenic levels consists of increasing linamarase activity in the roots. This, in turn, implies increasing the quantity and quality of protein available in cassava roots. Plant breeders at IITA have successfully crossed cassava with its wild relative, *Manihot tristis*, which is known to accumulate protein in its roots, to produce hybrids with a protein content as high as 8%. These hybrids are now being backcrossed to cassava, to incorporate other desirable traits. Success of these efforts would mean that (1) the roots would have an increased ability to shed their cyanogenic potential during processing, and (2) cassava consumers can get a higher protein content in their normal diets.

Potential impact

IITA scientists have thus joined in global efforts for a cassava that will provide improved nutrition. Considering that nearly one half of the world's cassava consumers are in sub-Saharan Africa, several million of whom are also the heaviest consumers of cassava anywhere, IITA's ecoregional mandate alone would justify a stake in improving this crop's nutritional quality. In addition, evidence from elsewhere in the world indicates that protein supplements in a cassava-based diet would be highly desirable.

Cassava is already very efficient in the production of carbohydrates. It provides 50% or more of the energy or calorie intake of many millions of its African consumers. These very facts emphasize the drive towards a higher protein content. Cassava also carries considerable protein in its leaves (up to 30% crude protein on a dry weight basis) and it can be effectively used—though this use is as yet largely unexplored—as a livestock feed. Add up those facts, and you will get a clearer idea of what the potential impact can be of cassava improvement efforts.

Cowpea improvement for traditional farming systems

During the past quarter-century, IITA cowpea research fulfilled its original goal of developing high-yielding varieties, for sole-cropping with different levels of inputs. In a parallel move which began late in the 1980s, the mainstream of IITA cowpea research became redirected, to improve local cowpea for intercropping with cereals in the dry savannas, with few or no inputs.

The redirection came about when high-yielding, monocropped cowpea had satisfied major demand globally, but had not really touched the needs of small-scale farmers in the dry savanna, where most of the world's cowpea is grown. In that region of poor soils and low rainfall, cowpea is intercropped with sorghum and millet. Its grains feed farming households, its leaves and stems feed the livestock, while rood residues enrich the soil for the next cropping cycle. Both grains and fodder are traded and generate income.

The current breeding program takes three paths in improving local cowpea for traditional farming. The aggregate task is to producing a yield of around 1 metric ton per hectare, which is more than 20 times the current yields of 25–50 kilograms per hectare.

The three paths are: (a) conventional breeding, (b) wide crossing, and (c) non-conventional breeding (biotechnology).

In addition, research in ecological modification will help reduce damage by insect pests: (d) biological control and cultural practices.

The multidisciplinary group of scientists who conduct the program has set a 5-year deadline by which to make a substantial achievement. If progress is insufficient within that frame, the whole endeavor will be reappraised.

Solo performance

Over 60 countries have received IITA-improved breeding lines for sole- cropping, in a wide range 1of agroecological environments. Those lines combine resistance to major diseases and insect pests with early maturity and preferred food grain qualities. About 50 countries have evaluated them and identified and released superior lines for cultivation.

Most of those varieties yield up to 2 metric tons per hectare within 60 to 75 days after planting and require only 2 or 3 applications of insecticide against the chief insect pests: *Maruca* pod borer and pod-sucking bugs. Breeding efforts continue to develop high-yielding varieties for monoculture, with medium or higher levels of inputs, to enable farmers who can obtain agrochemicals to realize the best possible harvests.

While that pleases farmers who have access to inputs, the high-performance cowpea cannot easily or economically be grown by small-scale farmers in traditional farming systems. Fertilizers and

For the farmer, the returns are greatest on improved local varieties

pesticides may not be available to them, or the prices may be out of their reach.

Local varieties grown without benefit of inputs yield 25–50 kilograms of grain per hectare. Such yields, according to 1992–1993 surveys by IITA, result from low cowpea planting density in millet or sorghum systems, combined with yield erosion from pests, diseases, and parasitic weeds.

Having developed varieties with 40 times those yields, IITA saw the potential difference that breeding could make for small-scale farmers. The first step is to stabilize the yield performance of farmer's varieties, through incorporation of resistance to flowering-stage pests (aphids and thrips), storage pests (bruchids), *Striga* and *Alectra*, and various diseases. The second step is to improve the yield potential of those improved varieties through selection for high yield with minimum inputs.

New cowpea varieties have already emerged from this process with increased productivity, producible on a sustainable basis and diversified, in order to suit different farmers' needs and conditions in different environments. Improved local cowpea has produced double the normal grain yields, or about 100 kilograms per hectare, in on-farm trials without the help of fertilizers or pesticides. The improved varieties will soon be ready for farmers' fields.

The conventional route

Conventional breeding aims to develop cowpea varieties appropriate for intercropping with millet or sorghum in the dry savannas, with few or no inputs. The base for this work is the research station at Kano, in northern Nigeria, jointly set up and run since 1990 by IITA and Ahmadu Bello University's Institute of Agricultural Research, at Samaru. A third collaborator is ICRISAT, which operates a field station at Bagauda, near Kano.

Technical support with plant physiology and agronomy has come from the Japan International Research Center for Agricultural Sciences (JIRCAS). JIRCAS scientists seconded to IITA have focused on abiotic stresses: tolerance of drought, shade, heat, and low soil fertility.

Farmers participated in the trials and in the evaluation. Their responses testified to the acceptability and potential for adoption and impact of the new varieties. The observed protection against bruchid storage pests was noted with satisfaction—the longer the grain can be stored, the greater the advantage for farmers in marketing their cowpeas and in keeping good seed for the next cropping cycle.

For the next round of improvement currently under way, breeders are focusing on drought tolerance, resistance to plant parasites *Striga* and *Alectra*, and ability to increase biomass (both grain and fodder material) despite poor soil fertility. Within 3 to 5 years, when they are ready for on-farm trials, the grain yield potential should stand at 200 kilograms per hectare.

Ecological rearrangements

Biological control and cultural practices are expected to double yet again, from 200 to 400 kilograms per hectare, the grain yield bonus from use of improved varieties.

Research into ecological approaches to yield improvement centers around the plant/pest/environment interactions and the possibilities for biological control of pests.

The cowpea's center of diversity appears to the southern Africa, although it was domesticated and has been widely cultivated in western Africa's dry savanna and Sahelian regions. In its center of diversity, the cowpea might be found with the same pests together with the pests' natural enemies, which had coevolved with the pests and the host plant. If natural enemies are found, IITA will study how to establish them in the newer areas where the pests have become established.

Two of cowpea's most troublesome pests—thrips (*Megalurothrips*) and the *Maruca* pod borer—appear to have had greater speciation and to have more parasites in southeastern Asia than they demonstrate in western Africa. West African countries are collaborating with IITA and other centers in investigating whether *Megalurothrips* in Africa is of exotic origin. *Maruca* is considered a minor pest in Indonesia and Malaysia, where perhaps there are more efficient natural enemies than in Africa. Collaboration with southeast Asian groups in studying cowpea/pest interrelations will begin in 1994.

A basic condition that cowpea pests face is their need for alternative hosts during the dry season, when the cowpea host is not available—before the rainy season begins, and after cowpea fades away for another year. They are "migratory." Alternative host plants of *Maruca* and *Megalurothrips* are being identified and examined, together with population dynamics of their resident pests and natural enemies.

Wide and wild

The best sources of genes for resistance to *Maruca* pod borer and pod-sucking bugs come from wild relatives of cowpea, outside its primary genepool, which poses great difficulties. The resistance genes must be transferred by wide crossing, to equip cowpea with desired traits. Tissue culture techniques involving embryo rescue are required.

Another wild cowpea source of promising resistance genes belongs to a group that crosses more easily with cultivated cowpea. With a strategy of accumulating the genes for resistance to *Maruca* and pod-sucking bugs, the genes can subsequently be transferred to a plant type which can be crossed through conventional breeding tactics to cultivated cowpea. IITA's main collaborators in wide crossing are *Università di Napoli* and *Istituto dello Germoplasmo*, Bari, in Italy, with Italian government funding support.

Yield gains of one-third to one-half of current levels are expected to accrue from wide crossing, being equivalent to a portion of the current losses from depredations of the pod borer and pod-sucking pests. Hypothetically, that gain would take grain yields from the level of savings

The Right Time for Yam

Revitalized research on a traditional favorite

Yam is a food crop for good times—synonymous with a full belly and general well-being. Yam is the most appreciated of staple food crops in West Africa and is known throughout sub-Saharan Africa.

Ironically, yam has never enjoyed much research priority in the drive to modernize African agriculture. Meager knowledge about yam physiology has militated against prominence in research programs; while basic knowledge has been available to the international community about such crops as rice, maize, even cassava, and permitted them a highly visible status.

Now, the time looks right to restore yam to its deserved place on the roster of research priorities.

1. More farmers seem to be growing yam than ever before—despite the lack of research support, yam cultivation is pushing into northerly areas of the moist savanna.

2. Yam has the postharvest qualifications for convenience foods, particularly for the rapidly expanding urban markets. Processed yam products store easily and for long periods, as with cassava. Another advantage to yam (which cassava and other tropical roots and tubers lack) is that the tubers can be transported easily and stored out of the ground for several months.

Bunson Fadare

Minisett technique helps boost yam production and conserve planting material

Gaining momentum

Over the past decade or more, an accumulation of research gains and signs of support for research and production have emerged. IITA, in the first instance, has the sole mandate within the CGIAR system for yam research and a collection of 2,660 accessions of yam germplasm, consisting of the 6 popularly consumed species and several minor species and wild relatives.

During the 1980s IITA researchers worked together with Nigerian national scientists to modify and popularize the minisett technology for producing high-quality, low-cost, and abundant yam planting material, to relieve farmers of the traditional need to set aside one-quarter of each crop to use as seed for the next. With this method farmers can produce 40,000 to 100,000 seed yams per hectare. The technique has been a boon for farmers as well as researchers, in making the job of germplasm preservation easier.

IITA has continued work in germplasm exploration and collection, in tissue-culture methodologies for breeding, and in yam diseases. Biotechnological techniques have facilitated characterization of yam genotypes. A molecular geneticist investigated the ancestry of cultivated yam, the results of which open new horizons for breeding. Two postdoctoral fellows were recruited in 1993 to strengthen yam research—a breeder/agronomist and a pathologist—who join the breeder/program head and a molecular geneticist already on the staff of IITA root and tuber crops researchers.

In 1993, the African Yam Network was founded, to enable scientists to support one another with infor-

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through environmental modification, being 400 kilograms per hectare, to 600 kilograms per hectare.

Protective proteins

Biologically active proteins should help in protecting cowpea from *Maruca*, pod-sucking bugs, and storage insect pests. New genetic sources to improve protection against *Striga* and *Alectra*, and drought-tolerance, are also in the pipeline.

The biotechnological capability of IITA and other advanced labs in a global network is needed in moving those proteins into the cowpea genotype. Applications of biotechnology in cowpea improvement work are coordinated among the collaborators: the Italian institutions at Naples and Bari, the two US universities of Purdue and Auburn, and Gent University, Belgium.

In a 1992 breakthrough, IITA developed a regeneration system through tissue culture that opens up opportunities to transform cowpea genetically—to endow it with genes which promote insect resistance.

Gains from biotechnological research hold promise of fostering another doubling of grain yields, up to 1,200 kilograms per hectare.

Chances of success with cowpea improvement for traditional farming appear high, judging from current progress on many fronts with many collaborators. Hence, even in this period of declining availability of funds, IITA continues to accord priority to cowpea research, honoring the researchers' 5-year commitment.

mation and technology exchange. The network has started life with 10 member institutions and a secretariat at Cotonou, Benin. Its founding marks renewed commitment to yam research from national programs, even in the face of dwindling support for agricultural research on the global level.

Partnership is needed at this stage of development in yam research. There are enough small centers of interest and resources to pack a punch together, with the right coordination.

In terms of local support, yam is a perennial favorite of consumers and producers, and is thus a priority for researchers in West African national programs. Approximately 90% of the world's production comes from the 6 countries stretching from the western flanks of Cameroon's mountains eastward to the Bandama river in central Côte d'Ivoire. Yam's center of origin is believed to be in the catchment area of the Niger River—the most densely populated part of tropical Africa. Over the many centuries of domesticating the yam, the various peoples who cultivated the crop developed complex social systems that gave yam a prominent sociocultural role.

Right time

The time seems right for IITA, with new capability in yam, to seize the opportunity to set a research agenda for regional impact.

The strategy for revitalized research in yam would aim to increase the knowledge base, strategic and applied, during the short to medium term. Investigations of yam physiology, taking advantage of biotechnological techniques, could support breeding research on which future improvement of the crop depends.

Farther downstream, research interests would relate to yield improvement, resistance to disease and nematodes, food quality (extending storage life and taste qualities that already distinguish the crop), and "engineering" characteristics—improving the shape for harvesting and handling operations, making it smaller and more uniform (1–2 kilograms, instead of the vastly bulkier tubers of 10 kilograms, sometimes up to 30 kilograms), and modifying growth habit, to reduce the work of staking, mounding, or digging deep holes in planting.

African scientists, in their own programs and at collegial gatherings, have oriented their research to help yam farmers modernize production, along the lines sketched in preceding paragraphs. They say that traditional preferences for big "ware" yams, the 20-to-30-kilogram tubers that are ceremonial symbols of prosperity and fertility, must yield to contemporary needs for convenient sizes for planting, harvesting, transporting, and processing. They are ready to help modify yam's traditional image, to make the farmers' task easier for the benefit of all.

Benson Fadare

A smaller size of yam than these may not please the eye so well, but will enable farmers to produce bigger yam harvests

A "modern" yam

The challenge is clear for yam: to take its place in the modernization of traditional agriculture in sub-Saharan Africa.

Traditional agriculture—of small-scale farmers who feed their families and send something to the market for a small cash income—is undergoing change under pressure from increasing population numbers. As the population grows, the available land is cultivated with reduced fallow periods. National economies put pressure on farmers to feed urban populations as cheaply as possible. Farmers feel ever more directly the effects of linkages and policy impacts through the spread of markets.

Research is finding the fit of other, more visible crops in this dynamic scenario.

• Maize has been adapted to the stresses of forest and savanna environments, lowlands and highlands, all over Africa; and is a crop grown by small farmers in all areas.
• Cassava has been adapted to all but the extremely dry environments of the humid and subhumid African tropics, and is fulfilling its foreseen role as a major calorie source in the race between population growth and agricultural productivity.
• And, looking to the great global example of all root crops, the potato has been transformed from a picturesque local staple to a mainstay of nations!

The research task for yam may even be less onerous than that for sister staples. It has no problematic condition to be worked around, such as cyanogenic potential. The research would build on yam's natural endowment of food quality characteristics and advantages of transportability and storage, to adapt them for contemporary farming and commercial requirements; and to adapt the crop to conditions in the range of targeted environments.

As yam's native lowland forests are cut down, the need becomes ever more urgent to collect germplasm materials and develop breeding programs which can modernize this root crop—a new crop for better times in hungry lands.

Plant Health Management

Highlights 1993

Developing solutions

Ecologically sustainable pest management systems must be developed and applied before farmers become excessively dependent on synthetic pesticides. Appropriate combinations of biological control, pest-resistant crop germplasm, and cultural practices are the basis of ecologically sound plant protection. In addition to those components, training for women researchers and socioeconomic dimensions of plant protection strategy compose the framework of a new IITA/CIAT integrated, multidisciplinary project on "Ecologically sustainable cassava plant protection" (ESCaPP), begun in 1993 with funding by UNDP. The African component of ESCaPP covers 4 countries: Benin, Cameroon, Ghana, and Nigeria.

Control of maize diseases and insect pests has been approached through: (a) a control campaign against downy mildew, which was launched in 1993 and which includes surveys to monitor downy mildew infection levels, fungicide residues, and residue buildup. Within 2 years, incidence of the disease is expected to be reduced in Nigeria and its spread contained. (b) characterization for control of maize pests and diseases by means of diagnostic field surveys, in Cameroon, Ghana, Côte d'Ivoire, and Uganda. Vector behavior will be studied and natural enemies of stem borers introduced.
(c) germplasm screening for resistance to stem borers, major diseases.

The plant parasite *Striga hermonthica* infests approximately two-thirds of African savanna areas, where maize has become a key crop in agricultural modernization. IITA has developed the beginnings of an arsenal against the pest. (See story on page 35.) PASCON has teamed up with IITA in combating various *Striga* species which plague croplands in its 27 member countries.

Storage losses in rural maize stores can discourage farmers from adoption of improved, high-yielding maize varieties. Such postharvest losses especially concern rural women, who are often responsible for maize storage, processing, and marketing.
The project to control the larger grain borer seeks to modify farmer crop-management practices in combination with improved technologies (biological control, genetic resistance) in order to prevent losses. The strategy is to identify the most effective traditional store management practices in rural Central American and West African stores, combining the most promising with complementary interventions.

Diagnosis for action

Recent diagnostic surveys are described in a story which begins on page 37.

Cowpea and soybean pest and disease problems were identified in farm-level surveys. (See related stories under "Crop improvement" in these pages.) Current activities include:
- development of environmental management measures which will incur minimal ecosystem disruption.
- identification of new sources of resistance in wild and cultivated germplasm; evaluation of the effectiveness and durability of resistance from new and existing sources.
- characterization of strains and ecotypes of pathogens and pests of cowpea; identification and testing of gene products which may control cowpea pests.
- evaluation of "trap" crops in biological control of postflowering pests.

Banana and plantain pests and pathogens were surveyed in East Africa, while West African surveys began or were under preparation. Sustainable control strategies are being developed through:
- cultural control—impact studies of the cleaning of planting material, the effects of weevil trapping, and crop management practices.
- biological control—studies of natural enemies of the banana weevil.
- host plant resistance—evaluation of resistance to major pests and pathogens.
- technology transfer—research collaboration, training with national programs.

Biological control

New developments include:
- cassava green mite—experimental releases of new natural enemy species.
- cassava mealybug—maintenance of small cultures of exotic beneficials, for use when pest spreads beyond Africa.
- mango mealybug—establishment of a second parasitoid.
- spiraling whitefly—collapse of pest populations when parasitoid introduced.
- water hyacinth—2 beneficial weevils established, initial impact documented.

A biological pesticide for locusts and grasshoppers was developed with spores of the fungus *Metarhizium flavoviride*, pathogen of the pests. Possibilities of applying it in an integrated pest management scheme were investigated. The results are contributing to development of a biopesticide for *Zonocerus* control. Fungus production and testing of technologies, including natural behavior-modifying chemicals, trapping, and socioeconomic research, have been expanded to 4 African countries.

Virus detection with monoclonal antibodies for African national programs

Plant diseases are a major threat to food production worldwide. The threat is especially severe in sub-Saharan Africa, where food production already faces an uphill struggle against population growth.

Viruses are only one among various causes of plant diseases. They are uniquely difficult to detect, identify, and characterize, making measures to relieve crops from their attack that much more difficult to design and apply.

Since 1990, IITA virologists and scientists from the Vancouver research station of Agriculture Canada have collaborated in an experimental research project with virologists and pathologists from 19 sub-Saharan African national programs. The activity has aimed at characterizing and identifying viruses in food crops, cowpea in particular, through application of serological techniques with monoclonal antibodies. The three groups of African, Canadian, and IITA scientists have exchanged information and participated in joint research that will continue to the project's end, in 1995.

Viral information

For many years, IITA scientists have been gathering information on viral diseases of plants, as well as identifying the viruses that cause them, clarifying their etiology, and characterizing their epidemiology. This facilitates their detection and enables application of control measures. IITA scientists have also been active in resistance breeding, which includes designing and applying effective screening techniques against the viruses.

In addition, improved plant materials of all of IITA's mandate crops are routinely tested for virus infections, so that seeds (or in-vitro cultures of germplasm) for use in collaborative testing with national programs are clean and do not carry seed-borne infections. (See accompanying story on seed health.)

Virus detection entails use of so-called antisera, or sera that contain antibodies, in serological techniques. The reliability of such techniques depends on the availability of a specific antiserum for each virus that is known to prevail in the region. For this reason IITA virologists have prepared antisera for many important virus diseases of mandate crops which are available to national program scientists for use in their diagnostic research.

These diagnostic reagents can be either "polyclonal" or "monoclonal," as a result of the way they are prepared, which in turn determines their characteristic specificity for particular viruses.

Monoclonal antibodies represent a distinct class of diagnostics which offers new opportunities for diagnosis of pathogens. They have been utilized in detection and identification of such plant pathogens as viruses, bacteria, spiroplasmas, and mycoplasma-like organisms. They can be group-specific or strain-specific—the serological technique provides the appropriate way of testing for an antibody with the desired specific properties. The use of monoclonal antibodies enables reliable information to be quickly collected on the identity, distribution, and importance of viruses and their strains.

Another advantage to monoclonal antibodies is that their quality characteristics are consistent, because they are reproduced by clones of the parental cell lines which are maintained as in-vitro preparations and stored for use as needed. Moreover, they can be produced as such, as absolutely specific and uniform antibodies, in unlimited quantities.

For such improved technologies to have their full impact, national programs in Africa must be able to apply the techniques effectively as well. Increasingly in recent years, IITA scientists and their African colleagues have worked to ensure that the programs can do so.

Hands on, together

IITA and Agriculture Canada, funded by Canada's International Development Research Centre (IDRC), have prepared monoclonal antibodies for

Hands-on in a multilateral effort to identify viruses of key food crops

important viruses and their strains which affect IITA mandate crops. In tion facilities and has started producing monoclonal antibodies for viruses present in Nigeria.

With the same Canadian support, IITA held 3 training workshops, one each year from 1991 at IITA headquarters in Ibadan, Nigeria, in which altogether 33 scientists from 19 African countries have taken part. The workshops have emphasized monoclonal antibodies and their reliability in diagnosis of virus diseases of crops that are important to African countries.

Those taking part in the workshops gained "hands-on" experience in identifying viruses and their strains, using serological techniques: in particular, the enzyme-linked immunosorbent assay (ELISA).

The trainees took home detection kits, including antisera, both monoclonal and polyclonal, which enable them to use these techniques in their own countries. Other supplies needed by national programs to make the serological tests effective have also been provided to them, with funds made available by IDRC. They have used these materials to collect virus samples for diagnostic studies and further research, the results of which should eventually contribute to the body of knowledge about viruses in crop production in the region.

With all the collaborative activities described here, national programs in Africa have strengthened their ability to detect viruses, which will help them as well as IITA in designing and applying appropriate control measures when a virus disease threatens a crop.

For its part, IITA has in this way acquired new, reliable information on a range of viruses from across the continent which will be useful in research into the diseases they cause and will

(continued on page 34)

IITA's Seed Health Unit

Making seeds safe

We all know that seeds carry the means to create future generations in their unpretentious packages. But they may also come with other trappings which we cannot readily detect: pathogens, in the form of bacteria, fungi, nematodes, or viruses. Such microorganisms can accompany seeds like so many freeloaders, waiting for the future plant to grow so that they can follow their own genetic imperative and do their damage to the crop.

As awareness of the problem and technical capability have grown, plant protection specialists have organized themselves to control these inimical organisms. Those in the CGIAR centers working with plant genetic materials have agreed to set up seed health units, which would be responsible for the health and safe handling of germplasm moving into or out of their centers. They are also working with other scientists to improve their diagnostic tools as well as seed treatment procedures, in order to reduce the risks of transmitting disease through seed.

In 1991, IITA created a research division of plant health management, bringing together scientists in all the major disciplines concerned with crop protection—pathologists, entomologists, and others. From this new vantage point away from their previous crop-specific positions, they could begin to address germplasm health issues in a holistic way and provide a single reference point in the Institute in phytosanitary matters. The new division established the Seed Health Unit during 1992 at IITA's Ibadan campus, with a core staff of one scientist, a research associate, and four technicians.

Before the Seed Health Unit existed, IITA scientists in the various crop improvement and support programs collaborated with the Plant Quarantine Service of Nigeria's Federal Department of Agriculture in meeting standards for safe transfer of plant materials in and out of the country. (Phytosanitary standards for Africa are set by the Inter-African Phytosanitary Council, which is part of the Scientific, Technical and Research Commission of the Organization for African Unity.) Treatment and handling procedures had varied according to

What we cannot see ***can*** hurt us—incubation helps bring that out; symptoms of *Cercosporo* or frogeye leaf spot disease on soybean

Moyo Bolarin

Traditional cowpeas can be improved, as this one has , as long as germplasm is maintained in good health

each program's research objectives as well as the official requirements for the crops concerned.

Now, to help in crop improvement and crop management work, the new unit advises researchers when handling or treatment threatens germplasm health or fails to reduce risks of disease transmission. The unit also represents IITA in national research and quarantine activities relating to germplasm transfer and seed health.

Prevention: the best cure The Seed Health Unit's main goals are to prevent (a) accidental introduction of plant diseases or pests, including seeds of the parasitic weed *Striga*, into new areas with the movement of germplasm samples; and (b) erosion of germplasm quality in stored materials because of the presence of disease-causing organisms.

During 1993, the Seed Health Unit routinely

- assessed seedborne pathogens in maize, cowpea, soybean, and cassava seed imported by IITA or produced by IITA for shipment to collaborators.
- evaluated health status of imported seeds by inspection of seedlings grown postentry in screenhouses.
- participated in field inspections of cowpea multiplication plots for seedborne diseases.
- tested small samples of IITA-produced true seed of hybrid plantain for the presence of pathogens.

The Seed Health Unit works with IITA's Virology Unit and Genetic Resources Unit in all matters related to germplasm movement. The Virology Unit has long been routinely testing breeding lines for viruses and began, in 1992, to eliminate viruses from cowpea seed in the IITA germplasm bank, by multiplying the seed in screenhouses in isolation from insect vectors and destroying plantlets that show signs of infection.

The Seed Health Unit examines germplasm samples visually and performs laboratory tests to detect the presence of pathogens. The new Unit also examines samples being grown in the field or screenhouse for disease symptoms and reviews the phytosanitary procedures of IITA's various crop programs to determine where improvements are needed. IITA plant breeders thus receive feedback on the efficacy of their seed handling and treatment.

A long-term activity of the Seed Health Unit is inspection and cleaning of IITA's cowpea genetic resources, which comprise the world's key collection of that commodity. In respect of phytosanitary standards and quarantine regulations, the Unit is investigating safe limits of pathogens on seed. The Unit is also studying seed transmission of specific pathogens of cowpea and soybean. It aims to develop new means of rapid detection and identification of pathogens.

Together with Nigeria's Plant Quarantine Service and National Seed Service, the IITA Seed Health Unit will continue work begun during 1993 to build a database on pathogens found in Nigeria. The European Plant Protection Organization has supplied software on pathogens that should be quarantined, for use in construction of the database.

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benefit many African countries. IITA scientists hope to continue playing a useful role in producing monoclonal antibodies of viruses and other pathogens of major African food crops, as a means of helping African national programs to address urgent field problems in food production. Information exchange activities among IITA and the national programs will continue beyond the life of the IDRC-funded project.

Striking back at *Striga*

Striga, a parasitic plant, is sweeping through the sorghum and maize country of Africa's savannas and highlands. The parasite can spread in those areas because it thrives under conditions of intensifying land use and reduced plant diversity—conditions which are worsening as population pressure on the land increases.

FAO has estimated that two-thirds of cultivated savanna areas are infested with *Striga hermonthica*, which can cripple cereal production (sorghum, maize, and millet) by taking over whole fields of the crop. Cowpea is parasitized by *S. gesnerioides*, another *Striga* species widely distributed in Africa, which has caused yield losses of up to 85% of the crop.

IITA's multidisciplinary *Striga* task force of 10 scientists is collaborating with national program scientists in affected African countries, as well as with advanced laboratories overseas, to help farmers turn the tide against the parasite by making local conditions hostile to its growth. They are using tactics of:

1. Fortifying the crop itself—endowing maize and cowpea germplasm with genetic resistance.
2. Practicing evasive management tactics in farmers' fields—treating maize and cowpea seeds with herbicidal chemicals, transplanting sorghum seedlings, practicing crop rotations, deploying non-host crops to "trap" the parasite.
3. Modifying the environment—introducing biological control agents hostile to the parasite, without need for farmer intervention.
4. Enlisting national programs in a continentwide campaign of research and extension activity, based on IITA control strategy and technologies.

The drive behind IITA's *Striga* research is the need in sub-Saharan Africa for sustainable, easily adoptable technologies for *Striga* control at minimal cost.

IITA seeks to select combinations of control interventions that are suited to specific socioeconomic and environmental conditions. Such packages of options are designed to have positive environmental effects. That is particularly true for crop rotations with food legumes which reduce amounts of *Striga* seeds in the soil, while improving soil fertility and providing vegetable protein for household consumption.

Two on the shelf

Already available to farmers are two maize hybrid varieties that show moderate levels of resistance to *S. hermonthica* and are adapted for cultivation under moist savanna conditions of rainfall and length of growing season: Oba Super 1 (hard, white grain) and Oba Super 2 (hard, yellow-orange grain). Pioneer Hi-bred Seeds Ltd., the Nigerian branch of the multinational seed company, currently sells altogether about 500 metric tons per year, with distribution in Nigeria and the neighboring countries of Benin and Cameroon.

Newer, more resistant hybrids are well along in experimental development. During 1993, international trials of *Striga*-resistant hybrid maize varieties were held in savanna areas of 6 West African countries: Benin, Cameroon, Côte d'Ivoire, Ghana, Nigeria, and Togo. Under severe infestation, 6 hybrids were identified with high and stable resistance across trial locations, to 2 *Striga* species: *S. hermonthica* and (in Togo) *S. asiatica*. They also showed high resistance to drought and diseases (maize streak virus, lowland rust, blight).

The resistant maize hybrids appear to control *Striga* through two modes of genetic action; through (a) control of damage that the *Striga* can inflict on the maize plant; and (b) reduction in emergence of the parasite. The resistance appears to be polygenic in character, with a quantitative inheritance—"durable" resistance—rather than based on a single gene action, which would diminish in potency from generation to generation.

IITA maize breeders are emphasizing the second mode—maize lines currently show sufficient *Striga* "tolerance", but should show greater ability to reduce emergence of *Striga* in the field. Encouraging progress was reported in that direction, from 3 years of trials in Nigeria. Two hybrids (8322-13 and 8425-8) resistant to *S. hermonthica* scored significantly less in emergence of parasite and in plant damage than did susceptible hybrids, while producing 85% and 51% greater grain yields, respectively.

Open-pollinated maize varieties are being investigated as desirable options for farmers who retain their own seed from the year's harvest to grow the subsequent year, and who may have limited access to fertilizer and other inputs. Two new sources of resistance to *S. hermonthica* for open-pollinated synthetic maize varieties are very promising:

- Several selections of *Zea diploperennis*, a wild relative of cultivated maize (*Z. mays*), showed high resistance in 1992 and 1993 trials. They have been crossed with maize to transfer the resistance.
- Some *Tripsacum* species, from 50 accessions contributed by CIMMYT, appear almost to be immune to the parasite. They show promise for use in improvement of resistance in maize populations already adapted to African growing conditions.

Evading the parasite

The host crop can evade the parasites's grasp through use of several crop management tactics being developed for farmers.

Protection of the host crop from *Striga* during the first 4 to 6 weeks of plant growth appears to promote significant reduction in crop loss and in the parasite's reproduction. Two ways to protect the crop in this way hold promise for technology development: (a) seed treatment (for cowpea, maize) and (b) transplantation of seedlings (for sorghum and millet).

Other evasive tactics are (c) use of non-host crops ("trap crops") and (d) rotation of crops in a pattern to deter *Striga* germination and parasitism on cereal hosts.

Seed treatment Seed soaked in dilute concentrations of imazaquin, a herbicide, has been a very effective treatment in control of *S. gesnerioides* and *Alectra vogelii* on cowpea, in lab and screenhouse trials. Imazaquin blocks biosynthesis of amino acids in the parasite.

The plantlet, germinates and seeks attachment. It perishes when it tries to attach itself to the "poisoned" host.

The good news is how economical the treatment is estimated to be—from \$3 to \$10 per hectare, depending on concentration of the treatment and planting density. Recommended concentrations are well below toxic levels for other crops. Another bonus of this technology is that African farmers are familiar with the practice of treating seeds.

Research on seed treatment for cowpea is relatively advanced, in field testing for appropriate concentration and planting density, because cowpea is resistant to the herbicide.

IITA is investigating appropriate treatments for maize seed in collaboration with the Dupont de Nemours & Co. and the University of Nantes, France.

Transplanting sorghum Maize and sorghum are typically planted in the same field during the same season in the moist savanna, so planning for *Striga* control must take both crops into account. Sorghum can withstand transplantation—indeed, it is a traditional method of stand establishment in some African cropping systems—but maize is not readily transplantable.

Transplanting of sorghum seedlings which are between 4 and 7 weeks old in screenhouse and field experiments helps to avoid much yield loss from *S. hermonthica* and significantly reduces reproduction of the parasite on the transplants as well.

Our resistant hybrid produces a large ear, even as it plays host to the parasite

R. N. Versteeg

In farmer-managed trials in Benin during 1993 (see story on page 42), sorghum seedlings free of *S. hermonthica* seeds were transplanted in fields together with cowpea trap crops. Emergence of the parasite was clearly reduced, equally in fields where fertilizer was applied and was not applied.

The tender trap The roots of some crop and weed species, apart from staple cereal crops, exude chemicals which can stimulate germination of *Striga* species; but they do not support development of the parasite as true hosts do. The *Striga* seed bank in the soil can gradually be depleted by setting such "traps" to stimulate germination in the absence of a viable host plant.

Promising non-host or trap crops for *S. hermonthica* and *S. gesnerioides* are being tested for integration into cropping systems as mulches, cover crops, or intercrops. IITA has identified several cowpea, soybean, and cotton cultivars from diverse accessions which are efficient as trap crops against *S. hermonthica*. Trap crops effective against *S. gesnerioides* have also been identified: two sorghum cultivars and cultivars of pigeon pea, bambara groundnut, and *Lablab purpureus*.

The National Cereals Research Institute in Nigeria is screening soybean cultivars for use against *S. hermonthica* in sorghum cropping systems.

Nigeria's Pioneer Hi-bred Seeds Ltd. also distributes IITA-improved soybean cultivars which are promising as trap crops for *S. hermonthica*.

Rotations One way to sap the potency of the *Striga* threat would be to deplete the parasite's seedbank in the field, by use of a non-host plant which is not a regular crop. As in the case with trap crops, the "non-crop" non-host would be planted to encourage germination of *Striga* seeds in the soil; but it would not support their development and would reduce the levels of viable *Striga* seed in the soil. This form of trap crop would be planted in rotation with regular crops.

Promising weed species for potential use in "non-crop" rotation are being screened for potent stimulants of *Striga* germination, both *S. hermonthica* and *S. gesnerioides*.

Recruiting new allies

Several soil-borne fungi and bacteria hold promise as biological control agents for reducing amounts of viable parasite seeds in the soil and in stopping parasite reproduction. IITA conducted a complete assay of *Striga* incidence, pre-reproductive wilt, and above-ground damage by insects and fungi in Benin during 1991 and 1992. Isolates of fungi found during the survey are being tested on *Striga* for pathogenicity.

Bacterial pathogens of *Striga* are being investigated for potential development into host seed treatments or inoculum for field application. Several fluorescent *Pseudomonads* and a *Xanthomonad* are apparently pathogenic on *S. hermonthica* without detriment to cultivated crops. If results from further testing are successful, those bacteria should offer a sustainable approach to control of *S. hermonthica* at seed stage, before it parasitizes the host crop.

Cooperative R&D

The complexity of the *Striga* problem, because of its numerous species and strains as well as the many crops that it affects, invites collaboration among different institutions that have complementary strengths.

In the belief that effective development and application of control technologies lies in cooperative exchanges with national programs, IITA joined FAO and other resource groups in the Pan-African *Striga* Control Network (PASCON) in 1988, to promote national research, training, and extension programs.

With IITA's strong support, the network has held three technical workshops since 1990 and, by the end of 1993, had expanded its membership to 27 African countries, 5 advanced laboratories in Europe and the USA, and 3 CGIAR centers—IITA, CIMMYT, and ICRISAT. During 1993, IITA provided *Striga*-resistant maize germplasm to 20 countries for their adaptive research.

IITA training activities include 2-to-3-week regional courses in research methodologies for scientists from many African countries; 3-to-5-day in-country programs to help upgrade research facilities and staff skills; and individual training at IITA headquarters for laboratory technicians from national programs. IITA's *Striga* research group is preparing a comprehensive handbook on research methods for use in those training programs. IITA's graduate research fellowship program also provides degree-level training opportunities in *Striga* research.

Within the next few years, IITA proposes to expand research activity in non-host or trap crops, by (a) extending its in-vitro methods for screening of trap crops, (b) developing an Africawide database on cultivars and cropping systems effective in *S. hermonthica* control, and (c) organizing a regional training program in trap crops research.

Diagnostic surveys help find remedies for plant health problems

Crop production worldwide is threatened by insects, diseases, and weeds. These stresses are particularly acute in sub-Saharan Africa, where nations can hardly afford further losses as food production is already declining per capita in the region as a whole.

If protecting crops from such pests is not to be simply a fire-fighting exercise, as it often has been in the past, preventive management measures have to be put in place, based on adequate information by way of advance warning. Diagnostic surveys of representative areas or ecosystems where the crop is grown are essential to this process, backed up by periodic monitoring.

Diagnostic surveys identify the presence and distribution of key insect pests and diseases, on both the crops being studied and alternative host plants. They help assess impact from the spread of known diseases and insects, in addition to spotting new ones as they emerge. Data gathered from surveys are then analyzed, as required, so that remedial measures can be designed and applied.

Many of our readers are well aware of the success of IITA's campaign over recent years for the biological control of the cassava mealybug, *Phenacoccus manihoti*, by the wasp, *Epidinocarsis lopezi*, in many countries of Africa. That success was, in part, backed by surveys of the crop, the pest, and its natural enemies, followed by studies that analyzed the complex plant/pest interactions at various levels within the agroecosystem.

IITA scientists have, in recent years, carried out such surveys with respect to various other crops within its mandated region in Africa: cowpea and soybean in Nigeria, maize in various countries (Benin, Cameroon, Ghana, Nigeria, and Uganda), and plantain/banana in Uganda (to be followed up by similar studies in Ghana and Nigeria). Some of these surveys are in initial stages, with follow-up action, including planning of the research needed, still in progress. Others have already been followed up by research that has indicated possible solutions.

IITA scientists work closely with their colleagues in national programs in planning and carrying out these surveys, as well as in determining the follow-up research required. They thus help augment the capability of national programs to carry out similar tasks as and when necessary. Since most surveys would need to be repeated every few years to catch up with changes in the interim, this in itself is an important contribution. A few examples follow.

Maize

Maize was introduced into Africa from its native Central and South America in the 16th century. It became the most important cereal crop in East Africa over succeeding centuries. In recent decades, its importance is increasing in the moist savanna areas of West Africa as well, both as an integral component of farming systems and as human food. The total maize-growing area in Africa is estimated at 21 million hectares. Average farmer yields are low (800–1200 kilograms per hectare), far below the world average (3700 kilograms). Numerous diseases, insect pests, and weeds contribute to these low yields.

IITA's efforts over the last two decades have been devoted mainly to host plant resistance to diseases and insects considered to be major threats. Considerable success has been achieved with resistance to maize streak virus and downy mildew (the latter in active partnership with the Nigerian national program), while moderate levels of resistance have been identified in the germplasm to blight and rust, and to the weed *Striga*. But only low levels of resistance have been achieved with insect pests, and only for some of the known insects. More efforts are clearly needed.

We need to know types and extent of damage by all pests, to direct breeding efforts best

Moyo Bolarin

Intensive diagnostic surveys can pinpoint exactly what these efforts should aim at. To help ensure that they do so, IITA scientists have been carrying out an analysis of the maize ecosystem in West Africa and in some countries of Central and East Africa, to assess the pest status of various organisms and to help predict how changes in ecological conditions would affect the pest incidence and status.

Several stem and cob (or ear) borers rank high in importance. With some important exceptions, these are native to Africa, where native grasses and sedges host them. Maize offers these pests a succulent feeding option. Focusing on one or two major maize pests—as in the past—would not adequately safeguard the crop from losses unless other potential threats in the immediate environment are considered as well.

Countrywide surveys carried out in Cameroon during the first and second growing seasons of 1993, in collaboration with national program scientists, yielded important new information with regard to the potential control of stem and ear borers. This has been added to information gathered since 1991 from 55 locations in northern Nigeria, and during 1990 and 1991 from more than 200 fields in Ghana.

A survey of all maize-growing areas of Uganda was also conducted in the second half of 1993, and a second one is planned for the first planting season of 1994.

Surveys during 1993 in Cameroon and Uganda also yielded important information on the incidence of maize streak virus, maize mottle/chlorotic virus, and fungal diseases, such as leaf blights, rust, and downy mildew. Research proposals to address these problems will be developed in consultation with national scientists. A coordinated eradication attempt for downy mildew is being planned for Nigeria, beginning in 1994, following research efforts in earlier years.

Cowpea and soybean

Cowpea and soybean are among the most important food legumes grown in Africa. Cowpea is grown widely by subsistence farmers in sub-Saharan Africa, who account for some 6 million of the 7.7 million hectares on which the crop is grown worldwide. It is an important protein source for low-income people. But several insect pests and diseases, as well as weeds, severely constrain production. Past research efforts in host plant resistance have had some notable successes, especially with diseases and with insects attacking seedlings and stored grain. But progress overall, especially with other insects, has been moderate, emphasizing the need for integrated efforts to achieve pest control.

Periodic surveys throughout the cowpea growing season commenced in 1991 and continued through 1993 in northern Nigeria. They monitored through repeated farm visits insect and disease problems within cowpea cropping systems. The data are being analyzed, to classify symptoms and quantify damage, in relation with agronomic variables. A study sample of 47 cowpea farmers was interviewed to draw upon indigenous knowledge on pests and their control, consisting mainly of traditional agronomic practices. Other surveys included alternative herbaceous and woody plants, which could also serve as hosts for cowpea pests, following similar surveys over recent years in Benin.

Soybean, now the world's main source of vegetable oil and a high-protein source for livestock feed, is a crop relatively recently introduced into Africa (early in the 1800s). It is grown over appreciable areas in Zimbabwe, Nigeria, and Zambia, as well as in Cameroon, Côte d'Ivoire, Ghana, Kenya, and Zaire, where it is becoming an important food crop in rural homes. Among the limiting factors for soybean production in Africa are diseases, such as frogeye leaf spot, red leaf blotch, bacterial blight, southern blight, and aerial or web blight. At present, insect pests do not seem important, though the situation could change, especially if the crop spreads widely or rapidly. Reliable data on the occurrence of pests and diseases and their natural enemies would then be needed to regulate pest occurrence and damage.

Surveys in 1993 studied the effect of intercropping cereals with soybean on the severity and spread of frogeye leaf spot, following preliminary indications of lower disease severity in intercropped fields. Diseases or insects observed on forage legumes (being studied for potential integration into the farming systems) were examined to determine whether they were likely to spread to cowpea or soybean.

Plantain and banana

Plantain and banana together provide more than 25% of the carbohydrates and 10% of the calorie intake for some 70 million people in sub-Saharan Africa. Cooking and beer bananas are consumed heavily in the highlands of East and Southern Africa, while plantains are a staple in several countries of West and Central Africa. Sub-Saharan Africa accounts for about 35% of world production, but per capita consumption in some areas is considerably higher than the world average, indicating how dependent many African consumers are on plantain and banana.

In addition to being a staple food for rural and urban consumers, plantain and banana provide an important source of rural income, particularly for the smallholders who produce them in compound or home gardens. They are relatively high-value crops, in common with horticultural produce.

Severe yield losses have been observed in several countries over recent decades. These are attributable to exhausted soils, but also to leaf diseases, the banana weevil, and root nematodes. These losses have not been adequately assessed.

Diagnostic surveys were initiated in Uganda in 1992, in collaboration with the Ugandan national program. They used a combination of techniques: participatory rural appraisals, questionnaires, repeated farm visits, and use of geographic information systems data to develop maps of pests and diseases, determine their status, and provide essential data for control strategies. These will be followed up by in-depth studies of areas found important in the initial survey. Similar surveys will be repeated in other countries, in East as well as West and Central Africa.

Results of the surveys in East Africa are expected to be available in 1994, and for West Africa in 1995. Preliminary results from Uganda revealed considerable variations in pest incidence and damage across locations, which were only partly explained by elevation. Similarly, preliminary data suggest a strong relationship between timing of weevil attack and yield loss. These aspects will be investigated further.

Capturing the dynamics

In summary, what diagnostic surveys do can be equated in some aspects to aerial photography. By focusing on a particular spot at a particular time, they give us accurate snapshots of a specific problem and its occurrence. When several related snapshots are taken and pieced together, a more meaningful pattern emerges. The changing contours of the pattern reveal to the scientist how a disease, insect, or weed has spread, what damage it has caused, and what control measures may be applicable.

In order to keep the picture from getting too static or unidimensional, the scientist will have to stay alert to emerging questions, to rearrange the pieces in the puzzle, and to look for newer insights that might be revealed. Since the real-world dynamics of crops and their pests is ever-changing, understanding them sufficiently to control damage is challenging and fascinating.

International Cooperation

Highlights 1993

IITA signed an accord with the government of Côte d'Ivoire to establish a station for crop improvement research in the moist savanna zone. (See story on following page.)

Training

Training Program activity concentrated on individual, graduate-level training; in-country group training; and training materials production.

The Program also contributed to intercenter efforts in sub-Saharan Africa to organize joint training activities, which encompass research interests across traditional center-based training programs, in order to complement ecoregional restructuring of research activities.

Farmer participation in research and gender implications for research are two topical concerns in the CG system which the IITA Training Program is spearheading within the institute and incorporating into its perspective on program development.

Graduate research In 1993, IITA supervised 101 PhD students from 22 countries and 39 MSc students from 13 countries. Of those 140 students, 117 came from sub-Saharan Africa and 37 were women; 21 PhD and 20 MSc students concluded their degree programs (see "For the record," page 55); and 50 students started new research programs with IITA. Most of the students received financial support from IITA's Graduate Research Fellowship Program or donor organizations, which included UNDP, USAID, AGCD, and the Ford and Rockefeller foundations.

Group training Program orientation shifted fundamentally in 1993 from on-campus to off-campus training. IITA conducted a total of 9 courses off-campus and 9 on-campus for 264 participants, of whom 39 (almost 15%) were women. The last on-campus, production-oriented training course for the foreseeable future, the plantain research course, was held at the High Rainfall Station at Onne in November.

The off-campus courses were held in Benin, Burundi, Gambia, Ghana, Niger, and Nigeria. Workshops for national research staff were held in 5 countries (Benin, Gambia, Ghana, Malawi, Uganda) to prepare for in-country training courses.

Crop management aspects in on-farm research are being emphasized in the evolving in-country training scheme, with the aim of strengthening both research and communication skills.

Training materials Users indicate that IITA training materials have become important sources of information on agricultural research technologies for national programs in sub-Saharan Africa. The mailing list contains 170 research institutions, agricultural development projects, non-governmental organizations, and others in 45 countries.

During 1993, the Program produced 21 titles in the Research Guides series (in English or French), some of them new and others being updates of earlier titles. Number 50 in the series has been issued; 500 titles in use remains the ultimate target.

Training materials production has become part of the curriculum of in-country training courses assisted by IITA. Training materials staff helped plan and execute an international course at WARDA and a workshop at ICRAF.

Cooperative Projects

AFNETA Together with the International Institute of Environment and Development, AFNETA organized a training course on farmer-participatory research methods for on-farm research in alley farming, from 24 May to 4 June 1993 at IITA. AFNETA held its fourth annual general meeting at ILCA, 19–22 October 1993, at which IFAD pledged support for on-station research projects started during AFNETA's first phase (1989–1993).

Crop improvement With the impending close of USAID operations in Cameroon, the NCRE project wound down after 14 years of highly successful crop improvement research and institution building.

With the conclusion of the 16-year USAID funding program for the SAFGRAD project, IITA made preparations for a new network, West and Central Africa Maize Research Network (WECAMAN), to support maize research among 8 SAFGRAD countries, which annually produce over 200,000 tons of maize each. An impact assessment by a Purdue University team estimated that the internal rate of return to the SAFGRAD investment in public research was 73%.

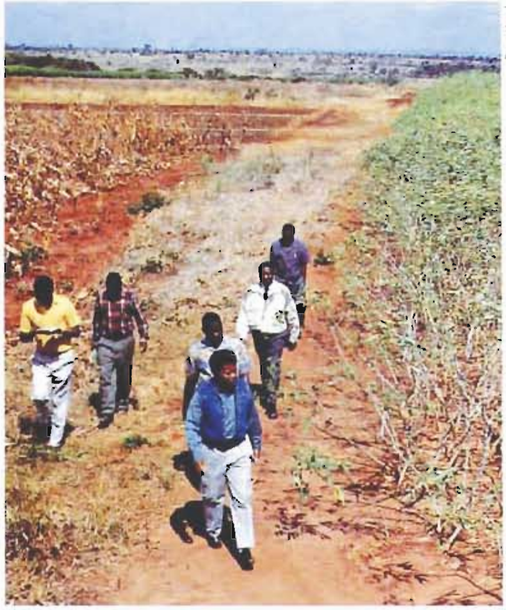
Two new networks took over support to root crops improvement research in eastern and southern Africa, with USAID funding, as ESARRN was phased out: the East Africa Root Crops Research Network (EARRNET) among 5 countries and the Southern Africa Root Crops Research Network (SARRNET) with 10 countries.

Cowpea research in Mozambique The SADC Cowpea Research Project came to an end in October 1993, with the following accomplishments, among others:

- cowpea market study to establish demand levels.
- definition of 4 main agroecological zones for cowpea in SADC region.
- start of a germplasm improvement program, in collaboration with Agronomy Faculty of Eduardo Mondlane University.
- first SADC cooperative cowpea trial, among all SADC programs (Botswana, Mozambique, Zambia, and Zimbabwe) in 1992, of 7 IITA lines and 5 from Mozambique selected after characterization of over 700 cowpea cultivars from IITA and SADC countries.
- 1 research seminar for 22 SADC participants in 1991, with publication of proceedings.

- 2 monitoring tours in 3 SADC cowpea-growing countries and Nigeria.
- 2 in-country courses in Maputo in 1991 and 1992.

Drought recovery in Malawi SARRNET estimates that over 200,000 farmers have been able to collect improved cassava planting material and 50,000 farmers improved sweet potato varieties, as a result of the US government-funded project in Malawi to expand production of the two crops following a severe drought period. Multiplication activity continued and on-farm evaluation trials were organized.



Equi Nwudu

Greening the drought-wracked croplands of Malawi

Two research liaison scientists assumed new assignments during 1993: Joseph M. Fajemisin in Côte d'Ivoire (covering 3 francophone West African countries) and Joseph B. Suh in Ghana (5 anglophone West African countries).

The research liaison scientist in Benin, Mark N. Versteeg, applied farmer-participatory research techniques in a new collaboration with non-governmental organizations in northwestern Benin, with rewarding results after only 1 year.

MOIST SAVANNA STATION

A savanna window for strategic research

IITA has opened a window for strategic research in the moist savanna zone of West and Central Africa.

In March 1993, the government of Côte d'Ivoire and IITA signed an accord to establish a research station at Ferkessedougou, in the northern part of the country near the border with Mali and Burkina Faso. The Moist Savanna Station is part of the *Institut des savanes* (IDESSA).

The addition of this reliable testing facility is a major advance in IITA's quest to develop new technologies for maize production in the high-potential agroecological zone of the moist savanna. With the surge in intensified production of maize across parts of the zone, from Côte d'Ivoire to Cameroon, the 12 countries that lie within the zone would like to take advantage of research results that can boost their maize production.

Screenhouse at Ferkessedougou: research on diseases of savanna maize

J. M. Fajemisin

The Moist Savanna Station will also serve as a base for research on other mandate crops of IITA (cassava, yam, cowpea, and soybean) in the diverse agroecological zones of Côte d'Ivoire. The station will facilitate collaboration with francophone countries in the region.

Breeding activities for development of high-yielding maize commenced during the year with identification of germplasm and testing of progeny for such characteristics as high yield potential, plant "standability," resistance to diseases and pests (including parasitic plants), and others.

IITA has set up a screenhouse for (a) mass rearing of the *Cicadulina* leafhopper and screening of maize plants for susceptibility to maize streak virus; and (b) evaluation of maize plants for resistance to *Striga hermonthica*.

The IITA scientists and a CIMMYT breeder who are assigned to the station have an administrative and residential base to the south in Bouake, near the headquarters of WARDA.

COMMUNITY ROOTS FOR RESEARCH

Farmers and NGOs bring Benin a bountiful harvest

The harsh, hazy light of the dry season presents the visitor in northwestern Benin with parched hills and crust-dry fields—an unforgiving landscape in rainless wintertime when farming families watch their food stores dwindle.

Nothing green on the ground—only mango trees defy the heat and goats to throw a leafy, welcome shade at intervals across the rolling savanna. A few spikey rows of millet stalks, left after harvest to protect scratching chickens from birds of prey, surround the mudwalled houses sentry-like against famine.

Unforgiving, but not forgotten—what looks like an immobilized land has a happier future in store, if the momentum of recent research efforts can be sustained.

An unusual research project took place during 1993 in northwestern Benin: in Boukoumbe district of Atacora province. Elements from the whole agricultural development community collaborated, with a say in the process at all times: from international organizations to bilateral donors to voluntary, non-governmental groups to the beneficiaries themselves: farmers and their families. After only 1 year's work, they produced results that farmers will use in choosing the crop mix for improved food security.

The moral of the story is that interactive, community-wide participation in research can produce remarkably useful results—unexpected as well as planned.

Protection

During the 1970s and 1980s the Benin government and the World Bank evolved plans for watershed protection and erosion control in northern Benin. A national park was set up in the mountains along the border with Burkina Faso, to preserve the forest environment and wildlife resources there. Assistance in erosion control and agricultural development was to be given in savanna lowlands to the south, to enable farmers to make a sufficient livelihood. If soils were degraded and became inadequate for farmers' needs, farmers would be forced to extend their cultivation into the reserve areas and thereby jeopardize the agricultural future of the region.

Coordinated by the World Bank, two multilateral projects started operations in 1992 and found mutual advantage in funding farmer-participatory research in Boukoumbe: the project responsible for protection of Benin's natural resources, *Projet de*

COMMUNITY ROOTS FOR RESEARCH

Founding of a forum with NGOs

"Define us by what we ***are***, not by what we are ***not***!" The suggestion came from a non-governmental organization (NGO) participant at a meeting in November 1993, to open a dialogue between IITA researchers and NGOs.

But when that plea comes from an NGO, what else can you say? NGOs are usually operated by groups whose one common characteristic is what they are ***not***: non-governmental.

So, "What's in a name?" goes the classic question.

A great deal, when it comes to NGOs. By their nature, NGOs pursue specific causes through activities which are, on the whole, highly focused. Dedicated to helping the deprived to realize their aspirations, most NGOs have a limited constituency, of their target beneficiaries and those who support the cause, and consequently a limited budget. (Some very large NGOs have a budget bigger than that of the CGIAR.) They depend for their success on responsive, flexible operations.

The example of NGO initiatives often shows government the way to make the greatest impact with larger-scaled public investments. Hence,

A good dialogue begins with good listening

gestion des ressources naturelles (PGRN), and that for restructuring of the various agricultural services, *Projet de restructuration des services agricoles* (PRSA). Both projects had funds to support activities by governmental and other agencies in aid of their respective goals.

The government had, by the beginning of the 1990s, become interested in extending the farmer-participatory methodology in different parts of the country, building on the success of the IITA-led project with mucuna and other technologies to restore soil fertility in the southern province of Mono. (See story on mucuna in *IITA Annual Report 1991*.) IITA and the Royal Tropical Institute (KIT) of the Netherlands, which had supported the Mono trials, saw a key opportunity in starting work in the Boukoumbe area before the end of 1992, while farmers were still active in their fields.

The timing was right to launch a project that would satisfy many-sided goals. The country's agricultural research authorities (INRAB—*Institut national des recherches agricoles du Bénin*) and the provincial branch of the government's extension services (CARDER/Atacora), both Mono collaborators, were ready to give technical assistance in another joint effort, backed with funds from PRSA (the chief source of funds), PGRN, and other sources.

Kim Atkinson

A happier future may be in store

In November 1992, therefore, INRAB organized a 1-week "rapid rural appraisal" jointly with IITA, KIT, and CARDER/Atacora, as a means of diagnosing problems from the farmers' perspective in relation with the national priorities. The results were to form the basis for a research plan for 1993, which would involve farmers and investigate erosion control and agricultural development in the threatened northwestern region. INRAB assigned an agronomist, a livestock scientist, and an economist to the survey.

Lucky

In implementing the survey, the team was most fortunate to find in many Boukoumbe villages the presence of voluntary, non-governmental organizations (NGOS). NGOS from overseas (France, Netherlands, and USA) as well as Benin were tackling the problems of hunger and poverty from different points of departure. The foreign NGOS had stationed their volunteer nationals in the area to work in selected villages on various projects, reinforced with cooperation from Benin counterparts who represented local NGOS or governmental agencies.

The luck of this discovery lay in brightened prospects for the government's search for solutions to the ecological predicament. Governments often benefit from the successes of NGOS, whose initiatives can show the way to make the greatest impact with public investments.

Of specific value for the work in hand, however, the survey team found the farmers to be receptive to their enquiries and proposals, in most of the villages where the NGOS had been working for some time. The NGOS, moreover, had a range of

they can exert significant influence in development programs, including those of agricultural research.

In sub-Saharan Africa, many NGOS have engaged in projects with kindred aims to IITA's own. Individual staff and projects have in the past collaborated with some NGOS in development-oriented research and technology-testing activities.

The accompanying article in these pages tells the story of one such collaboration in Benin, among IITA scientists, bilateral donors, governmental agencies, and NGOS, with farmers as participants and beneficiaries as well.

Dialogue

Recognizing their great potential in helping to promote IITA technologies in the field and obtain feedback on their performance from the farmers, IITA took steps to open a dialogue with a selection of international and national NGOS which run projects in the region. The objectives of the meeting were to:

- collect information on NGO activities in agricultural development.
- familiarize NGOS with IITA's goals, programs, and technologies to offer farmers.
- explore areas of possible collaboration.
- help to formulate a suitable strategy for IITA in relating to NGOS.

The 3-day "Dialogue with NGOS" took place at the IITA campus at Ibadan, Nigeria, from 15 to 17 November 1993. Twenty NGOS, in Côte d'Ivoire, Mozambique, many areas of Nigeria, and the USA, sent representatives to participate at the meeting. They range in size and scope from local, church-affiliated groups with farm-based training programs to transnational organizations active in diverse areas of development, such as World Vision International.

Consequent to the meeting, IITA's Board of Trustees endorsed the participants' suggestion that a consultative forum with NGOS be established. IITA liaison with NGOS will take place through the International Cooperation Division.

Kim Atkinson

Farmer patriarch and family of Kounagnigou greet visitors with bowls of sorghum brew

useful inputs to offer at no cost to the research sequel to the survey. The greatest single benefit was the help of village agents working for the NGOs—local people who were operating the NGO projects and communicating with the villagers about how to achieve their goals.

The oldest of the overseas organizations in the locale is the *Association française des volontaires du progrès* (AFVP), with a male and a female volunteer (French) working in a number of villages on grain storage and animal husbandry projects in 1993.

The *Nederlandse Ontwikkelings Organisatie* (Netherlands Development Organization—still known as "SNV" from an older name) had fielded a health care project in one Boukoumbe village from 1986. A Dutch woman had led an SNV project since 1990 to support women's economic activities in many more villages, as a means of improving their families' living status.

The US Peace Corps, active in Benin for some 25 years, had put a male volunteer in community and agricultural development in several Boukoumbe villages for a few years; at the time of the survey, one volunteer was serving with an agroforestry brief for hilly farmlands.

The NGO *Nonvigbè* from Oueme ("Association of Brothers and Sisters"), based in southern Benin, joined the Boukoumbe group to bring its experience in processing cassava to the SNV effort at improving women's skills and opportunities. Cassava was being introduced as an alternative crop to buttress the communities' food security. *Nonvigbè* had worked with food scientists from governmental units to develop techniques of processing cassava meal (in Yoruba: *gari*) and other storable products.

The French and Dutch NGO staff came equipped as professionals, who work according to a development plan with budgets for material supplies, vehicles, and manpower assistance. The Peace Corps volunteer has no institutional support as such, but mobilizes community resources to achieve shared goals.

Each NGO saw mutual advantage in combining forces with the governmental research project. The goals of environmental conservation through erosion control and agricultural development coincided with their own: with food security for AFVP, with agroforestry for the Peace Corps, and with women's development for SNV and *Nonvigbè*.

They found it natural, despite their different assignments, to be adopting a common program based on responses from the farming communities themselves. The project appealed to them as a window for their own development aims.

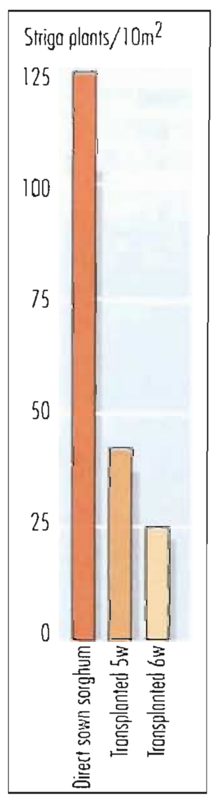
Striga first

After the rapid rural appraisal, the survey team invited the NGOs to select their own villages in Boukoumbe for the 1993 research project. SNV chose Koubentigou and Tanda in which to work together with *Nonvigbè*. The Peace Corps volunteer chose Kounagnigou. AFVP chose "Koumagou-B."

The farmers saw their main enemy in *itwari*, the name in the local language (Ditammari) for the parasitic weed *Striga*. *S. hermonthica* takes a severe toll of sorghum and millet, the region's staple cereals, and *S. gesnerioides* attacks cowpea. The three crops supply most of the region's food. Sorghum beer-making gives women some cash income. The crop residues provide construction materials.

Farmers also saw that declining soil fertility shared the blame for declining productivity.

It is reasonable to estimate that *Striga*, combined with soil fertility decline, accounts for a one-half reduction in normal sorghum yields in seriously affected areas such as Boukoumbe.



Erosion came third in their perception of the prime problems—even lower, in many of the surveyed villages.

Beyond these afflictions is the permanent danger of hunger. At the root of their problems is the farmers' inability to produce, with the resources in their environment, enough food for their families.

Anything which reduces

their productivity, such as *Striga* proliferation or soil degradation, or which increases the demand for the food they produce, such as population increase, makes their task just that more difficult. The overriding goal, for the farmers and for those who would intervene to ameliorate their lives, is to improve their food security.

Two goals

The government agencies, the NGOS, KIT, and IITA, with the farmers' views to guide them, set 2 main objectives for a 6-trial design in their project. They agreed to:

• develop, with farmers, feasible options for reducing striga infestation.

• seek alternative food production systems, to ensure food security.

Men and women farmers were eager to participate in the experiments. The design involved 80 farmers, 20 in each of 4 villages, in a set of 6 *Striga*-reduction and alternative-systems trials. (In one of the villages, where the Peace Corps volunteer relied on a young local fellow as the field agent, 5 farmers withdrew from the experiment before harvest time.)

An additional 6 farmers in 2 hilly villages participated in long-term, anti-erosion, agroforestry trials. (One of those farmers withdrew from the trials before the end of the year.)

The straightforward layout, a 2-tiered grid of 70-square-meter plots, emphasized the essential differences in treatments—in fertilizer application and between different crop varieties. Farmers could make their own comparisons between different treatments. They could easily see how fertilizer or its absence affected each crop combination. They could also easily tell the effects of different crop treatments on *Striga* or on total food production.

Seed, fertilizer, and technical assistance for the project were available to the participating farmers. The bonus in the whole experience, the NGOS' village agents (after training from the INRAB/KIT/IITA team) were frequently on hand to discuss the farmers' observations with them, increasing their confidence in the unfolding research results.

Striga on sorghum and cowpea

Two of the trials followed strategies to combat *Striga* in the traditional system of the staple food crops of sorghum (a "man's crop") and cowpea (a "woman's crop"):

1. Transplanting of sorghum (from a well-fertilized nursery) in relay with a local creeping variety of cowpea.
2. Introduction of IITA-improved, early-maturing, erect cowpea varieties; one with resistance to *S. gesnerioides*.

In both cases the cowpea performed as a "trap" crop, which provokes germination of *S. hermonthica* seeds in the soil, but does not support their development; hence, the *Striga* dies off without having reproduced itself.

Sorghum transplantation significantly reduced *Striga* infestation levels. (See figure, on opposite page.) Despite the clear *Striga* reduction, transplanting did not result in improved sorghum yields except in one village, Koubentigou, where

Two national researchers trade views with village agent on first cassava crop in Kounagnigou

Kim Atkinson

sorghum yields increased with transplanting after an early, erect cowpea trap crop. Fertilizer application did not reduce *Striga* infestation.

In Koubentigou and Tanda, farmers were quite positive about the transplanting technique after the cowpea trap crop. They suggested ways in which they could improve their results and planned to repeat the experiment next year.

Fertilizer significantly increased sorghum yields, which all farmers noticed. In Tanda, enthusiastic farmers misperceived the yield increase as suppression of *Striga* infestation, believing that fertilizer application resulted in reduced *Striga* infestation.

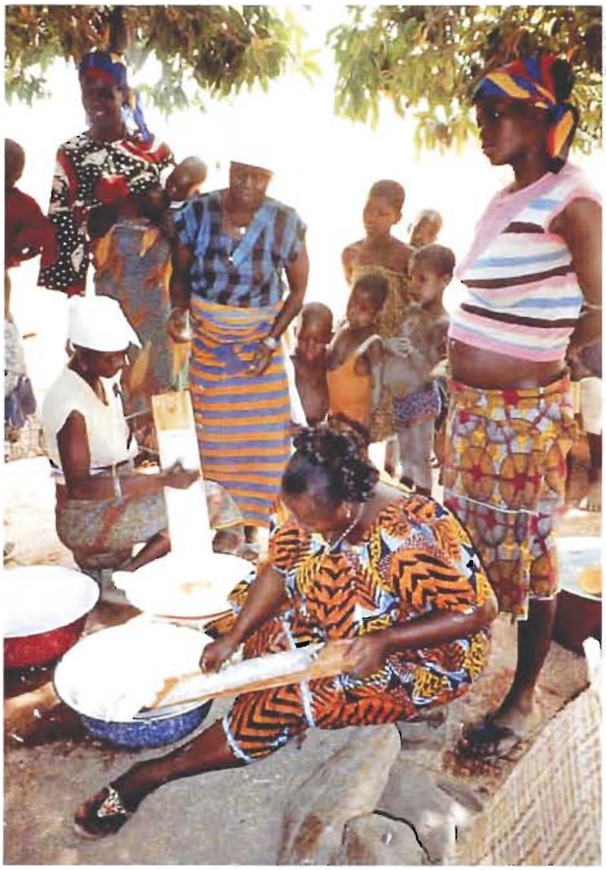
But for 60% of the farmers, the extra yield was insufficient to cover the purchase price of the fertilizer, particularly in the wake of the national CFA currency devaluation of January 1994. Some of the farmers reacted emotionally when they realized that they would not be able to afford fertilizer despite the attractive yields.

Transplanting of sorghum, in conclusion, reduced *Striga* in fields usually heavily infested. But in future transplanting should be employed with sowing of a trap crop early enough not to disturb the sorghum growth.

Cowpea yields, on the other hand, did not meet the women farmers' expectations. They had hoped for greater yields from the IITA varieties than actually materialized. The IITA-improved, early-maturing varieties outyielded the local early variety by only 10–20%. Its efficiency as a trap crop for *S. gesnerioides* could not be judged, moreover, because no one counted the associated *Striga* plants.

Densely sown as a trap crop before transplanting of sorghum, early cowpea more than doubled its normal yields (as a late-maturing variety) within the traditional sorghum/cowpea system. With 2 sprayings of insecticides, cowpea yields doubled again; but only a minority of farmers had high enough yields to support the cost of insecticide, had they been required to buy their own.

The women were interested in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Nonvigbé volunteer demonstrates cassava grating, while women of Koubentigou put hopeful hands to the new task

continuing experimentation with transplanted sorghum in the mixed cropping pattern. They realized that the modified system would have to be advantageous for men if it were to be adopted, no matter how well the cowpea itself performed.

Maize and cassava alternatives

Maize and cassava were introduced as alternatives to the main staple food crops of sorghum, millet, and cowpea, as means to boost food security at a time when soil problems and *Striga* threatened the traditional staples.

IITA's maize technologies for the savanna conditions of Boukoumbe included *Striga*-resistant hybrids. Improved and pest-resistant cassava for the savanna was also available—moreover, IITA and Benin had postharvest processing systems which potentially could be used in helping the farm families to improve their living standards.

The technologies had been developed for similar conditions in neighboring countries and were available "off the shelf." They looked to be adaptable to local conditions and acceptable to farmers without difficulty.

The most encouraging results of the whole experiment came from the maize/cassava combination:

- $5\frac{1}{2}$ times more food (in dry weight) from the maize cassava combination, with fertilizer application, than from the traditional (unfertilized) sorghum cowpea mixed cropping system.
- 4 times more food from cassava than from sorghum (in 3 of the 4 villages: where cassava was planted early enough to benefit from the rains).
- $1\frac{1}{4}$ more food from maize than from sorghum, without fertilizer, in low-density mixed cropping (15,000 plants per hectare).

Food security can be enhanced, it seems, without great difficulty. (See figure, below at right.)

IITA's *Striga*-resistant hybrid maize, Oba Super 1, was used in the trials. The relatively high prices of hybrid seeds and fertilizer, especially after the CFA devaluation, dampered the farmers' appreciation of the final results. Nonetheless, at current market rates, purchase of fertilizer would have been an economically attractive proposition for 80% of the farmers.

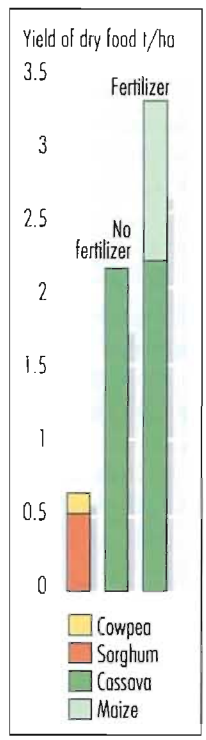
Maize planted at low density (1 plant per square meter) in unfertilized plots appeared to be able to capture the required nutrients. Further development and release of composite varieties at IITA should reduce the cost of new seed inputs.

Wild parrots and monkeys damaged some of the maize crops. In 2 of the villages, farmers outwitted the marauders by enveloping the ears in adjacent leaves and cutting the male flowers off the plants. In Kounangigou, however, several farmers were not free at the time to attend to the problem, which coincided with the harvest of *ipwoka* ("hungry-season rice;" *fonio*, in French), a vital part of their food security.

Cassava had not been much grown in the region, partly because the normal requirements (planting late in the rainy season and fencing the young plants during the dry season when livestock range freely to forage) do not permit extensive cultivation. An important innovation of the trials was planting early in the rainy season.

Three cassava varieties were selected for the trials: IITA-improved TMS 30572, Benin-improved BEN 86052, and a well-liked local variety from Save. They are clearly distinguishable and, as such, encourage farmer discussion and evaluation. In all 4 villages, TMS 30572 was the favorite because it had the best yields. Although the local Save was considered the sweetest and best-tasting variety, processing of the cassava into *gari* and chips eliminated taste differences.

Much of the interest in cassava stemmed from introduction of new processing tools and techniques by the Benin NGOs and IITA. Women especially stood to gain from the innovations, because cassava products are easily stored and can easily be sold to bring them cash income.



Women trainers from Oueme and the governmental *Direction de l'alimentation et de la nutrition appliquée* (DANA) demonstrated use of large- and small-scale equipment in the 4 villages. They had earlier visited IITA's Postharvest Engineering Unit and compared tools and machinery designed there with their own, for selection of the most appropriate for Boukoumbe.

The farmers' main concern about cassava was how to preserve their planting material between seasons. Fencing of the plantations usually failed because of grazing pressure from ranging livestock. One solution might be "living" fences: protection from tree species which appear to be inedible or repel the animals, such as *Jatropha curcas* (in French: "*pourghère*") and *Acacia auriculiformis*.

Agroforestry against erosion

The agroforestry trials sought farmers' evaluations of the usefulness of different leguminous trees and vetiver grass (*Vetiveria zizanioides*) in halting slope erosion, improving soil fertility, and providing fuelwood, among other benefits. However modest the current results appear to be, these long-term trials have survived the year in better shape than the researchers had expected!

Farmers did all the work in planting of some 4,300 trees of 8 "multipurpose" species in anti-erosion contour strips on hillsides. They planted another 5,000 in "protection forests" on stony or steep hilltops which would not have been cropped. They planted some 25,000 vetiver grass slips between the hillside rows of multipurpose trees.

The farmers reported that 4 of the species had survived satisfactorily and developed reasonably easily:

- *Leucaena leucocephala*
- *Acacia auriculiformis*
- *Gliricidia sepium*
- *Sennia siamea*

The vetiver survived mostly in good condition and had fostered some accumulation of soil organic matter by the end of 1993.

Ranging animals did strip the leaves off most of the tree species. The only untouched species, at the time of inspection, were *A. auriculiformis* and *S. siamea*.

The farmers were able to deter

Kim Atkinson

Hope for a more fertile future: Peace Corps volunteer with village agent and agroforestry trials

the predators early in the dry season by moistening the leaves and dusting them with powdered cattle dung. After a month or so the hungry cattle and goats began to eat the foliage nonetheless.

The Peace Corps volunteer observed that most *Gliricidia* leaves had been shed before the animals started to eat tree leaves.

Conclusion

The swift progress of the year's trials in anti-*Striga* tactics and alternative food crops shows the value of farmers' participation in the research from the beginning.

For the researchers, the success of the enterprise lay in the whole-hearted collaboration of the farmers which delivered credible results, that can be used directly to benefit the farmers and similar communities.

The key which unlocked all the possibilities was the confidence of the farmers in the researchers and their proposition. The researchers were able to secure the farmers' confidence because:

- First, the farmers had met them in association with the various NGOs, whose projects the farmers supported and benefitted from.
- Second, the researchers made the farmers' problems the focus of their trials. They did so because they knew that they could help that community only if they addressed the community's concerns, not simply their own planning priorities.

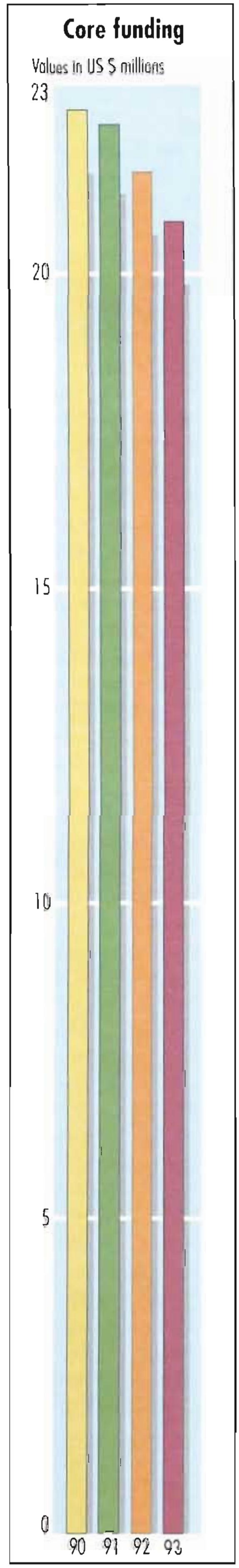
The story shows that subsistence farmers are willing to take risks in testing innovations when their own priorities are the subject of research. Boukoumbe farmers well understood the possibility of failure. Nonetheless, interest in the trials was so high that, in each village, there were more candidates for participation than the researchers could supply with materials.

The trial also shows that farmers' commitment is sustained when they can understand the trials and compare results in an uncomplicated layout of plots.

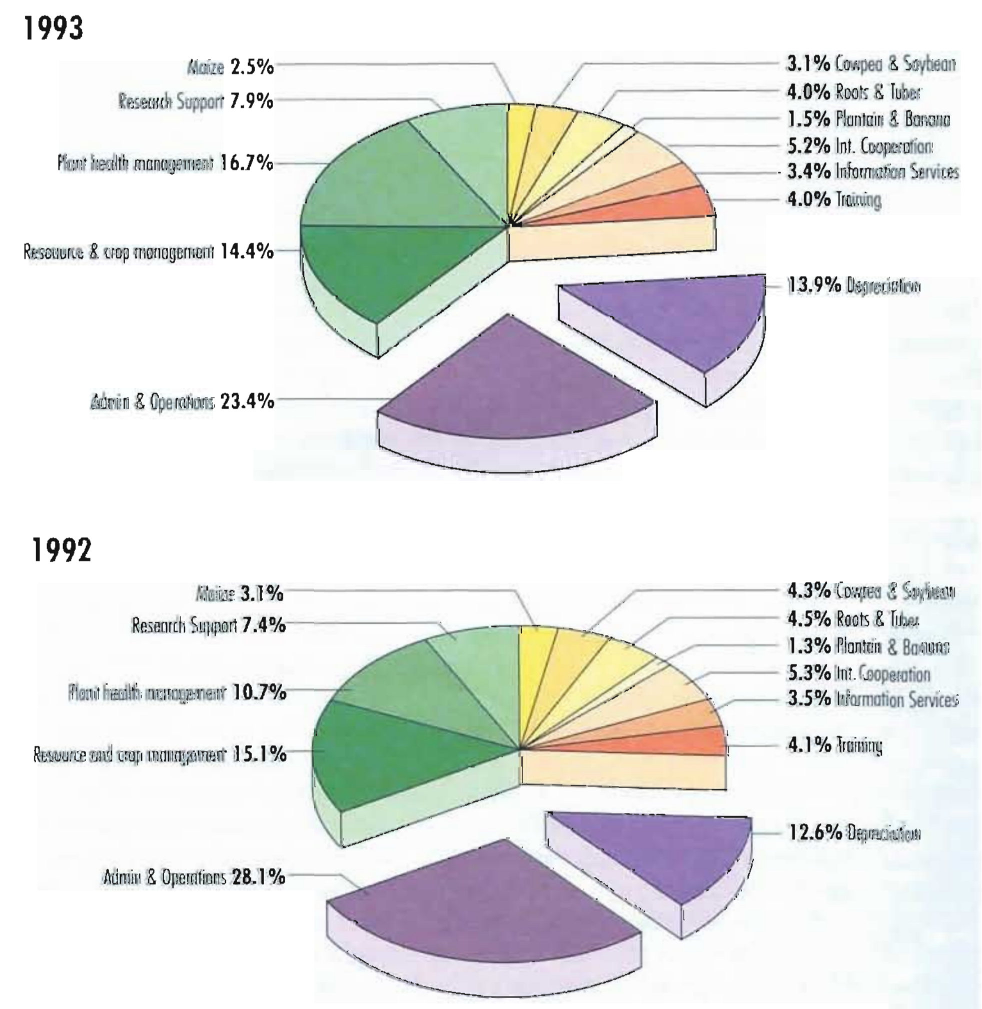
The same logic in the farmers' case worked in the collaboration with the Boukoumbe NGOs—they saw the essential congruence in goals, so they were willing to combine their own activities with the researchers' project. That collaboration provided another key to efficiency in the operations: the village agents, who became available for on-the-ground supervision of trials and the myriad tasks in implementing them. By the researchers' reckoning, effective local agents can take from 2 to 4 years to identify and train in working with farmers on research tasks.

For many farmers' problems, no clearcut solutions are on the shelf, ready for deployment. Technologies must be developed and adapted to particular situations. From the Boukoumbe experience, we can see that the whole R&D process can be telescoped when those involved at every level, from governmental planning to the roots of the target community, can communicate and combine energies to find suitable solutions together.

For the Record



Major resource allocations



Note:
The core budget is used to fund those research-related activities essential in meeting the CGIAR's objectives for developing countries

IITA

Statement of Financial Position

31 December 1993

Expressed in US $ thousands

** As restated*

ASSETS	1993	1992*
Current assets		
Cash and cash equivalents	14,735	14,063
Accounts receivable:		
Donors	5,428	6,893
Others	1,052	1,542
Inventories	1,125	1,041
Prepaid expenses	933	741
Other assets	265	278
Total current assets	23,538	24,558
Fixed assets		
Property, plant and equipment	62,817	61,223
Less: accumulated depreciation	32,736	30,279
Total fixed assets—net	30,081	30,944
Total assets	53,619	55,502

LIABILITIES AND NET ASSETS		
Current Liabilities		
Accounts payable and other liabilities	4,529	4,060
Accrued salaries and benefits	3,975	3,475
Payments in advance—donors	4,863	7,820
Total current liabilities	13,367	15,355
Net assets		
Capital invested in fixed assets	30,081	30,944
Capital fund	4,530	3,551
Operating fund	5,641	5,652
Total net assets	40,252	40,147
Total liabilities and net assets	53,619	55,502

IITA

Statement of Activity

31 December 1993

Expressed in US $ thousands

** As restated*

REVENUE	1993	1992*
Grants	34,086	36,424
Investment income	323	271
	34,409	36,695
EXPENSES		
Research programs	22,785	23,678
Conferences and training	2,114	2,026
Information services	738	756
General administration	3,016	3,924
General operations	2,634	3,220
Depreciation	2,991	2,722
Total expenses	34,278	36,326
Excess of revenue over expenses	131	369
Adjustment for change in accounting policy*	(142)	(520)
Deficit for the year	(11)	(151)

*Commitments (change in accounting policy)

Prior to 1 January 1993, purchase orders issued were accrued as operating expenses of the fiscal year in which they were issued irrespective of the date of delivery of goods and services. With effect from 1 January 1993, the CGIAR, in compliance with Generally Accepted Accounting Principles (GAAP), introduced the accrual basis of accounting which states that transactions and other events should only be recognized at the time when they affect the entity.

The net financial impact on the Statement of Activity for the years ended 31 December 1993 and 1992, as restated for comparison, is as follows:

		1993	1992
Operating commitments:	End of year	918	1,060
	Beginning of year	(1,060)	(1,580)
		(142)	(520)

IITA

Statement of Cash Flows

31 December 1993

Expressed in US $ thousands

** As restated*

		1993	1992*
Cash Flows from Operating Activities			
Deficit for the year		(11)	(151)
Adjustments to reconcile net cash			
Provided by operating activities:			
Depreciation		2,991	2,722
Adjustment for change in accounting policy		–	520
Reclassification of capital fund account		–	400
Gain on disposal of assets		116	145
Decrease (increase) in assets:			
Accounts receivable—donors		1,465	75
Accounts receivable—others		490	(624)
Inventories		(84)	66
Prepaid expenses		(192)	(741)
Other assets		13	(77)
Increase (decrease) in liabilities:			
Accounts payable and other liabilities		469	(745)
Accrued salaries and benefits		500	528
Payments in advance—donors		(2,957)	4,242
Total adjustments		2,811	6,511
Net cash provided by operating activities		2,800	6,360
Cash flow used in investment activities:			
Acquisition of fixed assets		(2,128)	(2,493)
		672	3,867
Net increase in cash and cash equivalents			
Cash and cash equivalents:	End of year	14,735	14,063
	Beginning of year	(14,063)	(10,196)
Increase in the year		672	3,867

IITA

Donors 1993

Expressed in US $ thousands

DONORS	Core Funding	Special Project Funding
Africa-wide Biological Control Program	-	865
African Development Bank	261	-
Austria	150	672
Belgium	555	660
BMZ, Germany	846	768
Canada	1,291	157
China	10	-
Commission of the European Communities	290	1,086
Denmark	371	336
Food and Agriculture Organization	-	31
Ford Foundation	-	205
France	268	67
India	25	-
International Development Research Centre	-	739
International Fund for Agricultural Development	-	53
International Institute of Biological Control	-	357
Italy	291	521
Japan	3,584	-
Korea, Republic of	50	-
Netherlands	1298	102
Nigeria	20	-
Norway	674	-
Overseas Development Administration (UK)	-	4
Rockefeller Foundation	61	451
Sweden	264	-
Switzerland	660	455
United Kingdom	600	-
United Nations Development Programme	-	868
United States Agency for International Development	5,050	4,677
University of Hohenheim	-	99
World Bank	4,200	-
Other contributions (ICRAF)	-	90
Closed and miscellaneous projects	-	4
Total	20,819	13,267

Inventory of Research Projects

Project title	Funding sources	Cooperating institutions	Locations	Duration
Crop Improvement				
Root and Tuber Crops				
Cassava germplasm introduction, evaluation, and distribution	core, CIAT	CIAT, EMBRAPA, NARS	Colombia, Brazil, Nigeria	continuous
Cassava germplasm enhancement	core, DANIDA	ANU, NARS, RVAU	Australia, Denmark, Nigeria	continuous
International collaborative trials	core, NARS	NARS	var. sites, W&C Africa	continuous
National coordinated research trials on cassava	NSS, RRPMC	NRCRI	Nigeria	continuous
Yam germplasm evaluation and distribution	core	NARS	var. sites, W&C Africa	continuous
Yam germplasm enhancement	core	NARS	var. sites, W&C Africa	continuous
Postharvest technology	core, NARS	NARS	var. sites, W&C Africa	continuous
Utilization of cassava for baking bread	BADC/FDC	KUL	Belgium, Nigeria	1992–1995
Technologies for germplasm distribution of pathogen-free *Dioscorea* yams	ODA	Wye College	UK, Ghana, Nigeria	1992–1995
Maize				
Maize breeding for the savanna				
Yield potential	core	IAR/Pioneer Hi-bred Co.	Nigeria	continuous
Striga resistance	core	NCRE/IRA, IDESSA	Cameroon, Côte d'Ivoire	continuous
Nitrogen use efficiency	core, GTZ	UI, Hanover	Germany, Nigeria	continuous
Drought tolerance	core	WECAMAN	Burkina Faso	continuous
Grain quality and utilization	core, Guinness Nigeria Plc	IAR&T/IER	Mali, Nigeria	continuous
Maize breeding for the forest zone				
Downy mildew resistance	core	IAR&T, Fed. College of Agric.	Nigeria	continuous
Stem borer resistance	core	UI	Nigeria	continuous
Husk cover and weevil resistance	core	UNB	Benin	continuous
Grain quality and utilization	core, Guinness Nigeria Plc	IAR&T	Nigeria	continuous
Maize breeding for the midaltitudes				
Yield potential	core	UTC, NCRE/IRA	Nigeria	continuous
Disease resistance	core	NCRE/IRA	Nigeria, Cameroon	continuous
Germplasm enhancement				
Striga resistance in maize landraces	core	—	Nigeria	continuous
Characterization of maize germplasm by environments	core	WECAMAN, CIMMYT	Nigeria, Burkina Faso, Côte d'Ivoire	continuous
Outreach				
WECAMAN	USAID	WECAMAN/USAID	Côte d'Ivoire	continuous
International trials	core	NARS	Nigeria	continuous
Collaborative research with NARS	—	NARS	Nigeria	continuous
Plantain/Banana				
Plantain/banana breeding for durable host plant resistance	core/BADC	INIBAP, FHIA, CRBP, KUL, NIHORT, CRI, IDEFOR, IRAZ, UNBRP, ICIPE, and other NARS	Cameroon, Nigeria, Uganda, Ghana, Côte d'Ivoire, Kenya, Malawi Burundi, Zanzibar	1987–
Developing *Musa* breeding capability and strategy	core	USDA/ARS, KUL	Nigeria	1992–
Banana improvement for the midaltitudes	core/USAID	NARS	Nigeria, Uganda	1992–
Biotechnology for *Musa* breeding	core	U Birmingham, USDA/ARS, KUL	Nigeria, USA, UK, Belgium	1983–
Postharvest quality of plantains	core	NARS	Nigeria, Ghana, Uganda	1992–
Genotype-by-cropping systems interaction	core	NARS	Nigeria	1980–
Genetic Resources				
Collection, characterization, documentation, conservation, and distribution of IITA's mandated crops and their wild relatives and of rice and some multipurpose tree species.	core/Italy	African NARS, IPGRI	sub-Saharan African countries	continuous
Interspecific hybridization and cytogenetics of *Vigna* species, biochemical characterization of cowpea and wild *Vigna*, cowpea regeneration and transformation.	core/Italy	Italian universities, Purdue U	Nigeria, Italy, USA	1988–95
Molecular methods for genetic mapping and detection of genetic diversity in *Vigna* species.	Rockefeller Fdn.	U of Minnesota	Nigeria, USA	1990–92
Edible root and tuber crop germplasm collection and conservation	core/Italy	African NARS	African countries	1990–

Project title	Funding sources	Cooperating institutions	Locations	Duration
Grain Legumes				
Cowpea varietal development for humid forest and Guinea savanna zones	core	—	var. sites, W&C Africa	1971–
Cowpea international trials	core	NARS	Asia, W&C Africa, Latin America, Asia	continuous
Nationally coordinated research on cowpeas	Nigeria	IAR	Nigeria	1975–
Cowpea improvement for cereal-based systems of moist and dry savanna—improvement of local varieties: genotype x environment analysis: resistance to *Maruca*, aphid, thrips, bruchid, and diseases.	core	IAR&T, ABU, ICRISAT, TARC VSO	var. sites, W&C Africa	1990–
Genetics of photosensitivity and phenological adaptation in cowpea	ODA	U Reading	Nigeria, UK	1993–
Development of cowpea varieties for SADC region	EEC	SACCAR/SADC	E&S Africa	1990–
Intercrop physiology of cowpea	core/TARC	TARC	Nigeria	1990–
Development of cowpea and soybean for Ghana	CIDA	CRI	Ghana	1985–
Soybean processing and utilization	IDRC	IAR&T, UNN, NAERLS	Nigeria	1987–
Accumulating partial resistance genes for *Maruca* pod borer in cowpea.	core	—	Nigeria	1993–
Intercropping soybean and sorghum	core	ICRISAT	Nigeria	1991–1993
Breeding for resistance to *Maruca* pod borer and pod-sucking bugs in cowpea using wide crossing	core	—	Nigeria	1993–
Studies on the genetics of resistance to *Maruca* pod borer in *Vigna ablongifolia*.	core	ICRISAT	Nigeria	1994–
Breeding for resistance to *Striga gesnerioides* and *Alectra vogelii* in cowpea	core	IAR, DRA, INRAN, Long Ashton Rsh Stn	Nigeria, Benin	1990–
Breeding for drought tolerance in cowpea	core	JIRCAS	Nigeria, Japan, Southern Illinois U	1991–
Soybean breeding for the savanna	core	—	var. sites, W&C Africa	1977–
Soybean international trials	core	—	var. sites, W&C Africa	1979–
Studies on promiscuous nodulation in soybean	NIFTAL/core	NIFTAL	Nigeria	1992–
Nationally coordinated research on soybean	Nigeria	NCRI, IAR, IAR&T	Nigeria	1980–
Biotechnology Research				
Cowpea plant regeneration and genetic transformation	Italy/core	Italian universities, Purdue U,	Italy, USA	1989–
Monoclonal antibodies and diagnostics	IDRC	Agriculture Canada	Canada, NARS	1990–1995
Application of molecular markers to root and tuber crops	IAEA/FAO	IAEA	Austria	1992–
Biotechnology for cowpea improvement	Belgium	U Gent	Belgium	1992-1995
Plant Health Management				
Cassava				
Studies on yield formation and interactions between the cassava plant, its pests, and the climate throughout entire growth cycle.	core		Benin, Nigeria	1982–94
Characterization of aspects of the biology and key interactions in the surrounding agroecosystem of *Mononychellus tanajoa*.	core, UNDP	EMBRAPA, CIAT, U Amsterdam	Benin, Brazil, Cameroon, Colombia, Ghana, Netherlands, Nigeria, Rwanda, Sierra Leone, Uganda, Zaire, Zambia,	1983–95
Effects of farming practices on the biological control of the cassava mealybug.	core	U Leiden, ETH	Benin, Ghana, Kenya, Malawi, Tanzania, Zambia	1988–95
Epidemiology of African cassava mosaic virus	core, ODA	NRI	Nigeria	1992–94
Yam				
Biology and control of yam anthracnose	core	NRI	Nigeria	1992–95
Maize				
Analysis of the maize ecosystem with focus on the most important lepidopterous pests in Africa.	core, GTZ	ICIPE, Texas A&M, IIE Simon Frazer U, U Reading, ICRISAT, NARS	Benin, Côte d'Ivoire, Ghana, Malawi, Nigeria, Cameroon, Niger, Guinea, Uganda	1989–95
Biology and epidemiology of *Striga* species; development of improved resistance screening techniques; improvement of resistance levels; studies on biological control, agents, development of agronomic practices for *Striga* control; development of predictive models for control strategies.	core, GTZ USAID	Old Dominion U, U Hohenheim, IAR, ABU, CIMMYT, ICRISAT, U Nairobi, Dupont Co., NCRI, U Bonn, U Gent, U Nantes	Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Nigeria, Togo	1989–95
Characterization of maize pathogens	core	IRA, IAR&T	Cameroon, Nigeria	1992–94
Biology of leafhopper vectors of maize streak virus	core	NRI	Nigeria, Uganda	1989–95
Downy mildew biology and control	core, World Bank, FAO, CIBA	IAR&T, state agricultural development projects (var.)	Nigeria	1993–1995

Project title	Funding sources	Cooperating institutions	Locations	Duration
Cowpea				
Feasibility study for the introduction of ecologically and economically sound pest management strategies adapted to subsistence farming systems.	core, SDC	ETH, U Laval, ABU, ILCA, ICRISAT, Purdue U	Benin, Burkina Faso, India, Nigeria, Niger	1987–96
Studies on virus diseases of cowpea	core	AUW, IRA	Cameroon, Mozambique, Nigeria	1990–94
Characterization of major pests and diseases in the northern Guinea and Sudan savannas.	core	IAR	Nigeria	1991–94
Screening cowpea varieties for resistance to pathogens in the dry savanna.	core	INRAN	Niger	1991–94
Soybean				
Studies on frogeye leaf spot disease	core	NCRI, EMBRAPA	Nigeria	1991–94
Biology of red leaf blotch	core	U Jos	Nigeria, Zambia	1991–95
Plantain/Banana				
Biology of *Mycosphaerella fijiensis*, causal agent of black sigatoka disease.	core	—	Nigeria	1991–94
Studies on virus diseases of plantain	core	U Minnesota	Nigeria, Benin, Ghana	1993–96
Screening plantain and cooking banana for resistance to black sigatoka.	core	FHIA, INIBAP	Cameroon, Nigeria	1991–96
Effects of ecological factors and agronomic practices on the pest status of black sigatoka, banana weevil and nematodes in highland bananas and plantain.	Rockefeller Fdn., SDC, BMZ	IIBC, CIAT, Agriculture Canada, U Laval	Benin, Nigeria, Uganda, Ghana	1989–95
Postharvest studies				
Studies on postharvest insect pests of maize	core, ODA	UNB, NRI	Benin, Nigeria, UK	1989–95
Studies on postharvest insect pests of cowpea	core	Purdue U	Nigeria, USA	1990–95
Ecological studies on the introduced larger grain borer in stored maize and cassava and in the surrounding habitats.	IFAD, SDC, BMZ	INIFAP, CP, CIMMYT, EAP, U Gottingen	Benin, Honduras, Mexico	1988–95
Aspergillus flavus prevalence and toxicity pattern	WI, BMZ	U Berlin	Benin, Germany, USA	1992–95
Seed Health				
Development of improved detection methods for seedborne pathogens	core	Plant Quarantine Service	Nigeria	1993–96
Studies of seedborne microflora of IITA mandate crops	core	—	Nigeria	1994–96
Biological control				
MANGO MEALYBUG				
Biological control of the mango mealybug by the introduced parasitoid, *Gyranusoidea tebygi*: quantification of impact in different ecological conditions.	SDC	U Leiden	Benin, Conakry, Côte d'Ivoire, Gabon, Ghana, Guinea, Nigeria, Sierra Leone, Zaire	1987–95
WATER HYACINTH				
Rearing, release, and monitoring of *Neochetina eichhorniae*, a beetle feeding on water hyacinth.	GTZ	CSIRO, IIBC	Benin	1991–95
BIORATIONAL CONTROL OF ACRIDID PESTS				
Joint biological control project agaınst locusts and grasshoppers using the fungus *Metarhizium flavoviride*.	USAID, CIDA, ODA, DGIS	DFPV, IIBC, Plant Protection Service	Benin, Niger, Mali, UK Niger, and Mali	1990–95
Biological control of spiraling whitefly, a polyphagous pest	FAO	IIBC	Benin, Togo, Ghana, Nigeria	1994–95
DEVELOPMENT OF NATIONAL BIOLOGICAL CONTROL PROGRAMS	GTZ, Austria, UNDP	NARS	25 sub-Saharan countries	1990–96
FAUNISTIC AND SYSTEMATIC STUDIES				
Development of insect museum to support ecosystems analysis	Austria	IIBC	Benin, Cameroon, Nigeria	1991–93
Resource and crop management				
Resource management				
Characterization of environments, resources and constraints				
Mapping of ecological and economic resource information and productive potential for West and Central Africa in a resource information system (RIS) and geographic information system (GIS).	AIDAB	ANU	W&C Africa	1990–
Characterization of resources and resource management in indigenous farming systems.	—	NCRE, IRA, NCRI	Cameroon, Nigeria	1988–
Characterization and development of the Mbalmayo site	AIDAB	CSIRO, Obafemi Awolowo, U National Herbarium, (Cameroon)	Cameroon	1991–

Project title	Funding sources	Cooperating institutions	Locations	Duration
Adaptability and adoptability of alley cropping systems				
Adaptive capabilities of hedgerow trees	USAID	U Hawaii, Michigan State U	Cameroon, Hawaii, Nigeria	1989–
Weed management in alley cropping	core	—	var. sites, W&C Africa	1989–
AFNETA research projects				
Multipurpose tree screening and evaluation (on-station)	USAID	ICRAF, Oregon State U	Cameroon, Nigeria	1990–
Alley farming management trials (on-station)	IFAD/IDRC/CIDA	—	var. sites, W&C Africa	1990–
On-farm research with alley farming	IFAD/IDRC/CIDA	—	var. sites, W&C Africa	1990–
Multipurpose capability of herbaceous and shrub legume-based cropping systems	core	—	var. sites, W&C Africa	1989–
Development of agroforestry systems for the humid forest zone	core	ICRAF, IRA, NCRI, OAU	Nigeria, Cameroon	1989–
Determinants of sustainability in cropping systems				
Concepts and methods in sustainability research	core	—	Nigeria	1989–
Long-term sustainability of alley cropping systems	core	—	Nigeria	1989–
Comparative systems studies	GTZ	Univ. of Gottingen	Nigeria	1989–
Development of models and support systems for integrated management of tropical soils				
Integrated nutrient management for acid soils	core	—	Cameroon	1988–
Nutrient cycling in alley cropping systems	core	TSBF	Nigeria	continuous
Dynamics of soil organic matter	BADC, DGIS	KUL, ISF	Nigeria	1988–
Regeneration of degraded soils	core	—	Nigeria	1989–
Biology and control of *Imperata cylindrica*	core	—	Nigeria	1988–
Crop management				
Humid forest systems				
Characterization and diagnosis of cassava-based systems	core, Univ. of Helsinki	U Helsinki	Nigeria	1989–
Collaborative study of cassava in Africa (COSCA)	core	Rockefeller Fdn, NARS	17 African countries	1986–
Strategic crop management studies	core	UI	Nigeria	1989–
Adaptability and adoptability of alley cropping	core, Ford Fdn.	UI, NIFOR, EEC	Nigeria	1986–1992
Development of improved technologies for cassava-based systems	core	EEC	var. sites, W&C Africa	continuous
On-farm validation and impact of improved technologies	—	NARS	var. sites, W&C Africa	continuous
Savanna systems				
Characterization and diagnosis of savanna systems	core	NARS in 17 countries	sub-Saharan Africa	continuous
Development of improved technologies for maize-based systems	core	IAR	Nigeria	continuous
Impact of improved technologies	core	DRA, CRI	Benin, Ghana	continuous
Integration of legume-based technologies into farming systems	core	NARS	Benin, Cameroon, Côte d'Ivoire, Ghana, Nigeria, Zaire	continuous
Impact of evolving production systems on *Striga*	core	IAR, NAES, IRA (North), PASCON/FAO	Cameroon, Ghana, Nigeria	continuous
Determinants and consequences of intensification	core	IAR, NAES	Ghana, Nigeria	continuous
Inland valley systems				
Characterization and diagnosis of inland valley swamp systems	DGIS, core	U Gembloux, WARDA, NARS	var. sites, W&C Africa	1990–
Mapping of ecological and economic resources information	DGIS	Winand Staring Centre	var. sites, W&C Africa	1990–
Strategic crop management studies	core	AUW, IIMI, ILCA	var. sites, W&C Africa	1990–

Project title	Funding sources	Cooperating institutions	Locations	Duration
International Cooperation				
NCRE				
Development of institutional capacity for research on cereals and facilities for transmitting research results to farmers	USAID	IRA	Cameroon	(Phase II) 1986–94
SAFGRAD				
Development of improved varieties of maize and cowpeas and improved cultural practices with farmers in semi-arid regions	USAID	17 Sahelian countries	Burkina Faso	(Phase II) 1986–93
SADC Cowpea Research Project				
Development of cowpea production in SADC countries	EEC	Angola, Botswana, Lesotho, Mozambique, Namibia, Swaziland, Tanzania, Zambia, Zimbabwe	Mozambique	1990–93
ESARRN				
Development of improved cassava and sweet potato varieties for sustainable production in East and Southern Africa	USAID, IDRC	Angola, Burundi, Ethiopia, Kenya, Madagascar, Malawi, Mozambique, Namibia, Rwanda, Sudan, Tanzania, Uganda, Zimbabwe	Malawi	(Phase II) 1992-93

Project title	Funding Sources	Cooperating Institutions	Location	Duration
AFNETA				
Applications of alley farming as a basis for sustainable farming systems	CIDA, IDRC, DANIDA, USAID, IFAD	Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Ethiopia, Ghana, Guinea, Liberia, Malawi, Nigeria, Rwanda, Sierra Leone, Tanzania, Togo, Uganda, Zaire, Zambia	Nigeria	1989–94
On-farm adaptive research for cassava, yam, rice, maize, cowpeas, and soybean in tropical Africa.				
Support for wide multilocation testing, multiplication, and distribution of improved varieties	EEC	Benin, Burkina Faso, Cameroon, Chad, Congo, Côte d'Ivoire, Equatorial Guinea, Gambia, Ghana, Guinea, Guinea-Bissau, Mali, Nigeria, Principe, São Tomé & Principe, Senegal, Sierra Leone, Togo, Zaire	Nigeria	1990–93
Utilization of cassava flour in baking bread				
Improvement in existing technology for baking bread, using pure and partially substituted flour	BADC/FDC	KUL, RVAU	Nigeria	1992–94
RRPMC				
Strengthening of NARS of West Africa to conduct adaptive research, and to promote increased regional collaboration with IARCs	France, CGIAR	Benin, Cameroon, Congo, Gabon, Guinea, Nigeria, Togo	Nigeria	1992–94
EARRNET				
Development of improved cassava varieties for sustainable production in East Africa	USAID	Burundi, Rwanda, Kanya, Madagascar	Uganda	1993–95
Training women professionals from West Africa	Ford Fdn.	ECOWAS countries of West Africa	Nigeria	1990–96
SARRNET				
Development of improved cassava and sweet potato varieties for sustainable production in the SADC countries	USAID	Namibia, Angola, Botswana, Malawi, Mozambique, Tanzania, Swaziland, Lesotho, Zambia, Zimbabwe	Malawi	1993–98
WECAMAN				
Development of improved maize varieties for sustainable maize production in West and Central Africa	USAID	Ghana, Togo, Burkina Faso, Caneroon, Côte d'Ivoire, Nigeria, Benin,Mali	Côte d'Ivoire	1993–95

Graduate research completed at IITA in 1993

Degree sought	Country of origin	University (U)	Sponsor	Name	M/F	Research topic
Crop improvement						
MSc	Belgium	KUL, Belgium	AGCD	Langie, H	F	Assessment of male sterility in natural *Musa* germplasm and plantain-banana hybrids
MSc	Belgium	KUL, Belgium	AGCD	Ulburgus, F.	M	Assessment of male sterility in natural *Musa* germplasm and plantain-banana hybrids
MSc	Nigeria	U Ibadan, Nigeria	Self	Akparobi, S	M	Morphophysiological adaptation of cassava to mid-altitudes
MSc	Nigeria	U Ibadan, Nigeria	Self	Chukwuma, S.	M	Classifying germplasm diversity in yam
MSc	Nigeria	U Ibadan, Nigeria	Self	Aliyu, Bakari	M	Taxonomic studies within the African wild Vigna gene pool Vigna reticulata Hooker fil
PhD	Botswana	U Zimbabwe	Ford Fdn.	Motgotsi, K.K.	F	Influence of low soil and air temperatures on yield and yield components of cowpea
PhD	Nigeria	U Ibadan, Nigeria	IITA/GRFP	Kehinde, Babatunde	M	Genetic linkage analysis in cowpea
PhD	Nigeria	Rivers State U of Science & Technology, Nigeria	IITA/GRFP	Harry, Gamaliel	M	Embryo rescue in vitro for the enhancement of hybrid plantain production
PhD	Nigeria	U Ibadan, Nigeria	IITA/GRFP	Ogbaji, M.I.	M	Genetics of resistance to pod-sucking bugs of cowpea
PhD	Nigeria	U Ibadan, Nigeria	IITA/GRFP	Adetimirin, V.O.	M	Maize characterization for *Striga*-tolerant mechanisms
PhD	Nigeria	U Ibadan, Nigeria	IITA/GRFP	Akintoye, H.A.	M	Nitrogen use efficiency in maize hybrid and open pollinated varieties
PhD	Nigeria	U Ibadan, Nigeria	IITA/GRFP	Fregene, M.A.	M	Phylogeny of wild and cultivated *Manihot* species based on restriction fragment length polymorphism (RFLP) analysis
PhD	Tanzania	U Ibadan, Nigeria	UNDP	Kapinga-Ndibaz, A.R.	F	Intercropping of cassava (*Manihot esculenta* Crantz) and sweet potato (*Ipomea batatas* L.) in the semi-arid zone of Tanzania

PhD	Zambia	U West Indies	SIDA	Simwambana, Moses	M	Physiological characteristics of spontaneous tetraploids and triploids as compared to those of diploids in cassava; effects of environment on flowering of cassava
Resource and crop management						
MSc	Belgium	KUL, Belgium	AGCD	Cornelissen, L	M	The evolution of land use entitlements in the Northern Nigeria
MSc	Belgium	KUL, Belgium	AGCD	Van den Bosch, S.	M	Soil organic matter
MSc	Ghana	U Helsinki	FINNIDA	Agyeman G. A.	F	The effect of burning on the weed seed bank and on weed establishment in the humid forest
MSc	Netherlands	U Wageningen		de Groot, E.	F	Earthworm effects on plant production and soil fertility
MSc	Nigeria	U Ibadan, Nigeria	Self	Chinwo, K	M	Survey on impact of fertilizer on ground and surface water quality in the Northern Guinea Savannah region of Nigeria
MSc	S. Leone	U College, Njala	IITA/GRFP	Kroma, M	F	Gender responsibility in post harvest practices and loss reduction technologies of small farmers
MSc	Belgium	U Bruxelles	AGCD	Convent, H.	M	Suitability of leaves of selected woody species as source of nutrients in alley croping and as feeds for small ruminants
PhD	UK	U Ibadan, Nigeria	Commonwealth	Liya, S.M.	F	Nitrogen fixation and nitrogen contribution by hedgerow trees in alley cropping systems
PhD	Nigeria	U Ibadan, Nigeria	Self	Awatoye, O.O.	M	Vesicular arbuscular mycorrhizal contribution on nutrient uptake and water use efficiency on hedgerow trees and the associated food crop in the alleys
PhD	Nigeria	U Ibadan, Nigeria	Self	Atayese, M.O.	M	Vesicular arbuscular mycorrhizal contribution on nutrients recycling and water relations of multipurpose trees and the associated food crop in the alleys
PhD	Nigeria	Ahmadu Bello U, Nigeria	IITA/GRFP	Ahmed, Benjamin	M	Economic analysis of the potential for sustained maize production in the northern Guinea savanna of Nigeria
PhD	Nigeria	U Nigeria, Nsukka	IITA/GRFP	Ezedinma, C.	M	Availability and use of farm labor in food crop production in cassava-producing zones of tropical Africa
PhD	Cameroon	U Ibadan, Nigeria	IITA/GRFP	Egbe, Andy E.	M	Litter fall and comparative study of two indigenous multipurpose trees for use in agroforestry systems in humid lowlands
PhD	Nigeria	Ahmadu Bello U, Nigeria	Self	Usman, Kyiogwom	M	Impact of adoption of improved maize varieties in the northern Guinea savanna of Nigeria
PhD	USA	U Florida, USA	Self	Latt, Christopher	M	The interaction among reserve carbohydrates, pruning strategies and biomass production of hedgerow tree species
PhD	S. Leone	U Minnesota, USA	IITA/GRFP	Freeman, Horatio	M	A model of agricultural intensification in the West African northern Guinea savanna
PhD	Tanzania	Reading U, UK	IITA/GRFP	Hongo, Haminu	M	Climatology of mixed and sole maize cropping systems
Plant health management						
MSc	Belgium	KUL, Belgium	AGCD	Wouters, Alex	M	A study of resistance mechanisms involved in various types of maize resistance to maize streak virus
PhD	Ghana	U Wales, Cardiff, UK	IITA/GRFP	Adu-Mensah, O.	M	Laboratory and field studies on infestivity of two species offungal pathogens to *Zonocerus variegatus* and grasshoppers in West Africa
PhD	Portugal	U Leiden, Netherlands	BCP/IITA	Boavida-Mégévand, C.	F	The mango mealybug and its biological control
PhD	Germany	U Giessen, Germany	GTZ	Borowka, Roland	M	Biological control of cassava mealybug in Malawi, especially *Diomus* spp.
PhD	Gambia	U California, Berkeley	BCP/IITA	Bruce-Oliver, S.	M	Evaluation of the indigenous African phytoseiid, *Euseius fustis*, as a biological control agent of the cassava green mite on cassava in West Africa
PhD	Switzerland	ETH, Zurich	Self	Stäubli-Dreyer, B.S.	F	Biology and feeding behavior of *H. notata* (Mullis.) (Coleoptera: Coccinellidae) in relation to its prey, the cassava mealybug, *P. manihoti*
PhD	Germany	U Giessen, Germany	GTZ	Langewald, Jürgen	M	Biological control of locust with neem
PhD	Germany	U Hohenheim, Germany	GTZ	Schaab, Ralf	M	Economics of biocontrol of cassava pests
PhD	Ethiopia	U Bath, UK	IIBC/IITA	Emiru, Seyoum	M	Locust pathogens
PhD	Benin	U Leiden, Netherlands	GTZ/IITA	Bokonon-Ganta, A.	M	Impact of the mango mealybug and its exotic parasitoids

IITA's improved germplasm released in different countries

Country	Crop	Breeding line/variety
Angola	Cowpea	TVx 3236
Belize	Cowpea	VITA-3
Benin Rep.	Cowpea	VITA-4, VITA-5
	Cassava	TMS 30572, TMS 30572A and TMS 4(2)1425
	Maize	TZB-SR, 43-SR, DMR-ESR-W, 30-SR
Bolivia	Cowpea	IT82D-442, IT82D-889
Botswana	Cowpea	ER-7, TVx 3236
Brazil	Cowpea	4R-0267-01F, VITA-6, VITA-3, VITA-7, TVx 1836-013J
Burkina Faso	Cowpea	TVx 3236, VITA-7 (KN-1)
	Maize	EV 8422-SR, EV 8430-SR, EV 8431-SR
Burma	Cowpea	VITA-4 (Yezin-1)
Burundi	Cassava	TMS 40160/3, TMS 40160/1
Cameroon	Cowpea	IT81D-985, IT81D-994, TVx 3236
	Maize	TZB-SR, TZPB-SR, TZB derivation, DMR-ESR-Y, Kasai-SR, Suwan 1-SR, 8321-18, 8556-6
	Cassava	TMS 8034, TMS 8017, TMS 8061 and TMS 82516
Central African Republic	Cowpea	VITA-1, VITA-4, VITA-5
Chad	Cowpea	IT81D-994
Colombia	Cowpea	IT83S-841
Congo	Maize	8644-27
El Salvador	Cowpea	TVx 1836-013J, VITA-3, VITA-5
Equador	Cowpea	VITA-3
Ethiopia	Maize	Gusau 81 TZB*, Gusau TZB-SR*
Fiji	Cowpea	VITA-1, VITA-3
Gabon	Cassava	CIAM 76-6, CIAM 76-7, CIAM 76-13, CIAM 76-33, TMS 42025, TMS 30555, TMS 30337, TMS 40160, TMS 4(2)1425
Gambia	Cassava	TMS 60142
Ghana	Cowpea	IT82E-16, IT83S-728-13, IT83S-818, TVx 1843-IC, TVx 2724-0IF
	Maize	49-SR, Pool 16-SR, 43-SR, QPM Pop63-SR
	Cassava	TMS 30572*, TMS 50395* and TMS 4(2)1425*
	Soybean	TGx 297-192C, TGx 306-036C, TGx 888-49C, TGx 536-02D, TGx 297-10F, TGx 813-6D
Guinea	Cowpea	IT85F-867-5
	Cassava	TMS 30572
Guinea Bissau	Cassava	TMS 4(2)1425, TMS 60142
Guatemala	Cowpea	VITA-3
Guyana	Cowpea	ER-7, TVx 2907-02D, TVx 66-2H, VITA-3
Haiti	Cowpea	VITA-5
India	Cowpea	VITA-4, TVx 1502
Jamaica	Cowpea	VITA-3, ER-7
Korea, Rep. of	Cowpea	VITA-5
Liberia	Cowpea	IT82D-889, TVx 3236, VITA-5, VITA-4, VITA-7
	Cassava	CARICASS 1, CARICASS 2, CARICASS 3
Mauritius	Cowpea	TVx 3236
Mozambique	Cowpea	IT82E-18
	Cassava	TMS 30001, TMS 30395, TMS 42025
	Maize	Matuba, SEMOC-1 (DMR-ESR-W)
Nepal	Cowpea	IT82D-889, IT82D-752
Nicaragua	Cowpea	VITA-3
Niger	Cassava	TMS 4(2)1425
Nigeria	Cowpea	IT84S-2246, TVx 3236, IT82E-60, IT81D-994, IT86D-719, IT86D-721
	Cassava	TMS 50395, TMS 30572, TMS 30001 TMS 4(2)1425, TMS 30555, TMS 91934, TMS 82/00058, TMS 81/00110, TMS 81/00661, TMS 90257, TMS 84537
	Soybean	TGx 849-313D, TGx 1019-2EN, TGx 1019-2EB, TGx 1448-2E TGx 536-02D, TGx 306-036C
	Maize: Open-Pollinated	TZPB, 096EP6, TZMSR-W, TZSR-Y, TZSR-W, TZEYR-W, TZESR-Y, DMR-LSR-W, DMR-LSR-Y, DMR-ESR-W, DMR-ESR-Y, TZB-SR, TZPB-SR, EV 49-SR, POOL 16-SR, Suwan 1-SR, EV43-SR
	Maize: Hybrid	8321-18, 8321-21, 8322-3, 8322-13, 8329-15, 8341-5, 8425-8, 8428-19, 8434-11, 8505-2, 8505-3, 8505-4, 8505-5, 8505-13, 8644-27, 8644-31, 8644-32, 8516-12, 8535-23, 8556-6
	Cooking banana	Cardaba
Pakistan	Cowpea	VITA-4
Panama	Cowpea	VITA-3
Peru	Cowpea	VITA-7
Philippines	Cowpea	IT82D-889
Rwanda	Cassava	TMS 30572, Gakiza (IYT bulk 1977), Karana (PYT bulk 1977)
São-Tomé	Maize	TZSR-Y-1, TZSR-W-1
Senegal	Cowpea	TVx 3236
Seychelles	Cassava	SEY 14, SEY28, SEY32, SEY41, SEY52
Sierra Leone	Cowpea	TVx 1999-01E
	Maize	TZSR-Y-1, EV 26-SR
	Cassava	ROCASS 1, ROCASS 2, ROCASS 3, NUCASS 1, NUCASS 2, NUCASS 3, 80/40
Somalia	Cowpea	TVx 1502
Sudan	Maize	DMR-ESR-W, DMR-LSR-W, Gusau TZB
Sri Lanka	Cowpea	IT82D-789, IT82D-889, TVx 309-01G, TVx 930-01B
Swaziland	Cowpea	IT82E-18, IT82E-32, IT82E-71
Tanzania	Cowpea	TK-1, TK-5, IT82D-889
Togo	Cowpea	VITA-5, TVx 3236
	Maize	49-SR, 8322-13 STR
	Cassava	TMS 4(2)1425 and TMS 30572
Uganda	Cowpea	TVx 3236, IT82E-60
	Cassava	TMS 30572*, TMS 60142*, TMS 30337*
	Maize	Acr 83 TZMSR-W, 8535-23, 8556-6
Venezuela	Cowpea	VITA-3
Yemen	Cowpea	TVx 3236, IT82D-789, VITA-5
Yemen (South)	Cowpea	VITA-5, VITA-7
Zaire	Cowpea	IT82E-18
	Maize	83TZMSR-W, Ik 83 TZSR-Y-1
	Soybean	TGx 814-76D, TGx 849-294D
	Cassava	Kinuani, F100, TMS40230/3
Zambia	Cowpea	TVx 456-01F, TVx 309-1G
	Cassava	LUC 133

* Released in 1993/94

Abbreviations and acronyms used in the text

ABU Ahmadu Bello University (Nigeria)
AFNETA Alley Farming Network for Tropical Africa
AIDAB Australian International Development Bureau
ANU Australian National University
AUW Agricultural University, Wageningen
BADC/FDC Belgian Agency for Development Cooperation/Fund for Development Cooperation
BMZ Bundesministerium für Zusammenarbeit (Germany)
CABI Commonwealth Agricultural Bureau International (UK)
CGIAR Consultative Group on International Agricultural Research
CIAT Centro Internacional de Agricultura Tropical
CIDA Canadian International Development Agency
CIMMYT Centro Internacional de Mejoramiento de Maiz y Triga
CIP Centro Internacional de la Papa
CP Colegio de Postgraduados (Mexico)
CRBP Centre Régionale Bananiers et Plantains
CRI Crops Research Institute (Ghana)
CSIRO Commonwealth Scientific and Industrial Research Organization
DANIDA Danish International Development Agency
DFPV Département de formation en protection des végétaux (Bénin)
DGIS *Directoraat Generaal voor Internationale Samenwerking* (Netherlands)
DRA Direction de la recherche agronomique (Benin; Central African Republic)
EAP Escuela Agricola Panamericana (Honduras)
EEC European Economic Community
EMBRAPA Empresa Brasiléira de Pesquisa Agropecuária
ESARRN East and Southern Africa Root Crops Research Network
ESCaPP Ecologically Sustainable Cassava Plant Protection (IITA)
ETH Eidgenössisch Technische Höchschule (Switzerland)
FAO Food and Agriculture Organization of the United Nations
FHIA Fundacion Hondurena de Investigacion Agricola (Honduras)
GGDP Ghana Grains Development Program
GTZ Gesellschaft für Technische Zusammenarbeit (Germany)
IAEA International Atomic Energy Agency
IAR Institute for Agricultural Research, Samaru (Nigeria)
IARCS international agricultural research centers
IAR&T Institute of Agricultural Research and Training (Nigeria)
ICIPE International Center of Insect Physiology and Ecology
ICRAF International Centre for Research in Agroforestry
ICRISAT International Crops Research Institute for the Semi-Arid Tropics
IDEFOR Institut des Fôrets (Côte d'Ivoire)
IDESSA Institut des savanes (Côte d'Ivoire)
IDRC International Development Research Centre
IER Institut d'économie rurale (Mali)
IFAD International Fund for Agricultural Development
IIBC International Institute of Biological Control (UK)
IIE International Institute of Entomology (UK)
IIMI International Irrigation Management Institute
ILCA International Livestock Centre for Africa
INIA Instituto Nacional Investigaçao Agronomica (Mozambique)
INIBAP International Network for the Improvement of Bananas and Plantain (France)
INIFAP Instituto Nacional de Investigaciones Forestales y Agropecuarias (Mexico)
INRAN Institut national de recherches agronomiques de Niger
IPGRI International Plant Genetic Resources Institute
IRA Institut de la recherche agronomique (Cameroon)
IRAZ Institut de recherche agronomique et Zootechnique (Burundi)
IRRI International Rice Research Institute
ISF Institute of Soil Fertility (Netherlands)
JIRCAS Japan International Research Center for Agricultural Sciences
KUL Katholieke Universiteit Leuven (Belgium)
NAERLS National Agricultural Extension and Research Liaison Service (Nigeria)
NAES Nyankpala Agricultural Experiment Station (Ghana)
NARS national agricultural research systems (in Africa; various)
NCRE National Cereals Research and Extension (Cameroon)
NCRI National Cereals Research Institute (Nigeria)
NiFTAL Nitrogen Fixation in Tropical Agricultural Legumes
NIFOR Nigerian Insitute of Oil Palm Research and Training
NIHORT National Institute for Horticultural Research and Training (Nigeria)
NRCRI National Root Crops Research Institute (Nigeria)
NRI Natural Resources Institute (UK)
NSS National Seed Service (Nigeria)
OAU Organization for African Unity
ODA Overseas Development Administration (UK)
PASCON Pan-African Striga Control Network
RRPMC Regional Research Project on Maize and Cassava (IITA)
RVAU Royal Veterinary and Agricultural University (Denmark)
SACCAR Southern Africa Center for Cooperation in Agricultural Research
SADC Southern Africa Development Community
SAFGRAD Semi-Arid Food Grains Research and Development Project
SDC Swiss Development Corporation
TARC Tropical Agricultural Research Center (Japan)
TSBF Tropical Soil Biology and Fertility Program
U University
UC University of California
UI University of Ibadan
UNB Université nationale du Bénin
UNBRP Uganda National Banana Research Program
UNDP United Nations Development Programme
UNN University of Nigeria, Nsukka
USAID United States Agency for International Development
USDA/ARS United States Department of Agriculture/Agricultural Research Service
UTC United Trading Company (Nigeria)
VSO Volunteer Service Organization (UK)
WARDA West Africa Rice Development Association
WECAMAN West and Central Africa Maize Network (SAFGRAD)
WI Winrock International

Board of Trustees

* Left during the year (1 April 1993–31 March 1994)

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H. Izevbigie, MILR, planning/training manager*
F. O'Dwyer, BSc, nurse/practitioner
A. Ohanwusi, MBA, planning /training manager
O. I. Osotimehin, BSc; DDA, personnel manager

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T. Terao, PhD, plant physiologist—special project

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M. Bokanga, PhD, biochemist and food technologist
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S. Y. C. Ng, MSc, tissue culture specialist
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Postdoctoral fellow
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G. O. Olayode, farm management officer (Ibadan)

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S. Ferris, PhD, postharvest technologist

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J. Kling, PhD, breeder
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J. Henrot, PhD, soil biologist—special project
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Agroecological studies unit
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Postharvest technology
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Postdoctoral fellows
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* Left during the year (1 April 1993–31 March 1994)

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W. Meikle, PhD, entomologist—special project
K. Wydra, PhD, plant pathologist—special project
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W. W. D. Modder, PhD, entomologist

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D. K. Berner, PhD, *Striga* biologist
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Seed health unit
Postdoctoral fellow
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Postdoctoral fellow
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O. A. Osinubi, MSc, research training specialist
A. Oyetunde, MA, editor
R. Zachmann, PhD, training materials specialist

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J. Suh, PhD, Ghana (affiliated to PHMD)—special project
M. Versteeg, PhD, Benin (affiliated to RCMD)

Cooperative special projects

USAID/IITA Cameroon (NCRE) project
E. A. Atayi, PhD, chief of party and agricultural economist
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H. C. Ezumah, PhD, farming systems agronomist*
M. Kamuanga, PhD, agricultural economist
M. Moussie, PhD, senior agricultural economist/TLU coordinator*
J. A. Poku, PhD, agronomist*
G. L. Servant, PhD, administrative officer*
T. C. Stilwell, PhD, deputy chief of party
C. F. Yamoah, PhD, soil scientist/agroforestry

Semi-arid food grains research and development (SAFGRAD) project, Burkina Faso
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USAID/IDRC/IITA (ESARRN), Malawi
M. N. Alvarez, PhD, breeder, network coordinator*
J. E. Ikeorgu, PhD, agronomist*

CIDA/CIMMYT/IITA Ghana grains development project
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EEC/IITA/SADC cowpea project
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R. Amable, PhD, cowpea agronomist*
A. L. Dato, PhD, cowpea breeder*

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Southern Africa root crops research network (SARRNET)
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T. Malila, administrative officer
N. M. Mahungu, PhD, agronomist/breeder
A. Muimba-Kankolongo, PhD, agronomist/pathologist
M. Porto, PhD, agronomist

(WECAMAN)
B. Badu-Aproku, PhD, coordinator and breeder

Strengthening national/regional socio-economic research capacity in ESARRN countries
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Collaborative programs with IARCS
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M. A. Jabbar, ILCA
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J. Smith, ILCA
C. Williams, WARDA/CABI

* Left during the year (1 April 1993–31 March 1994)

Publications by IITA staff

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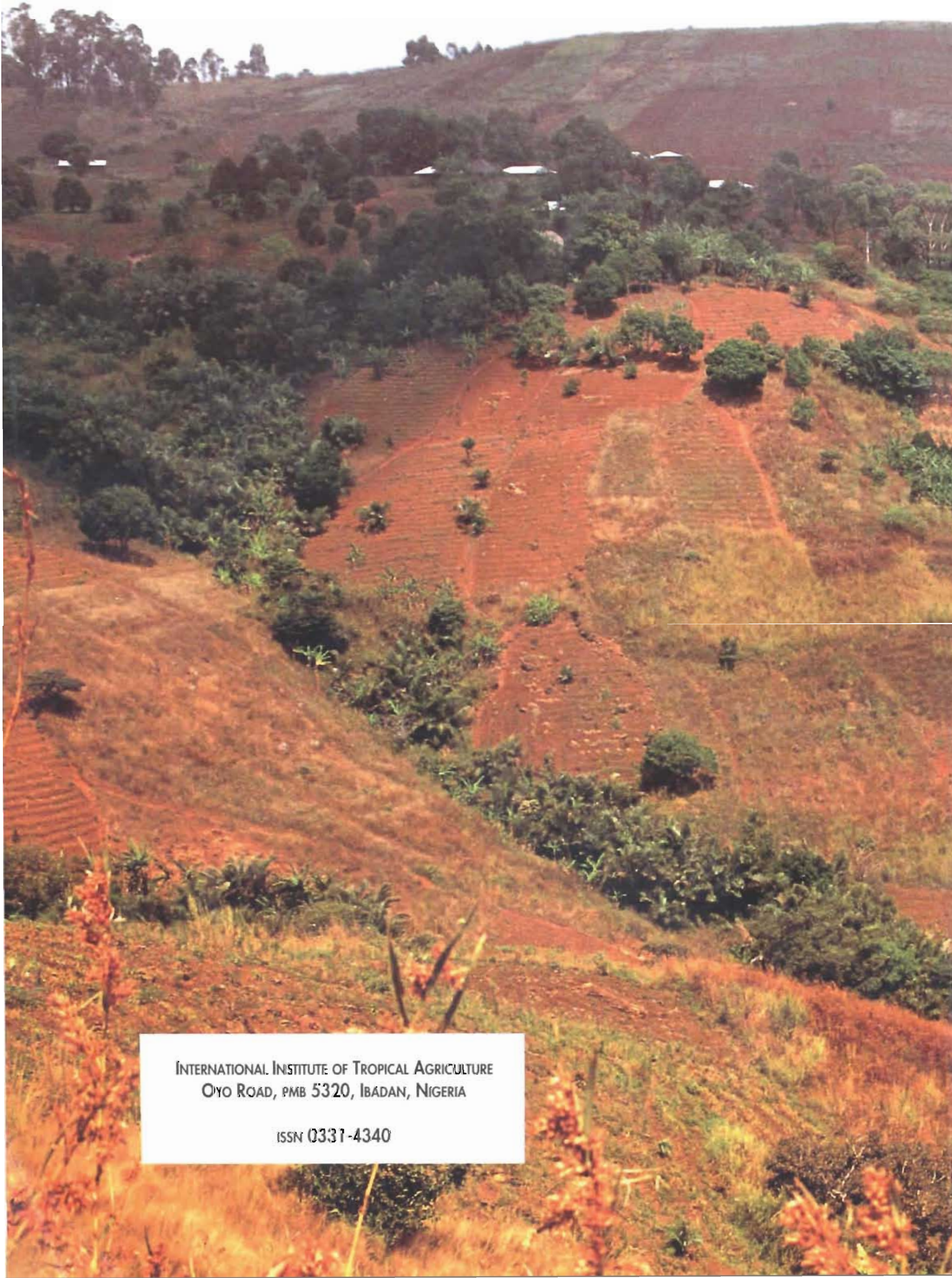

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